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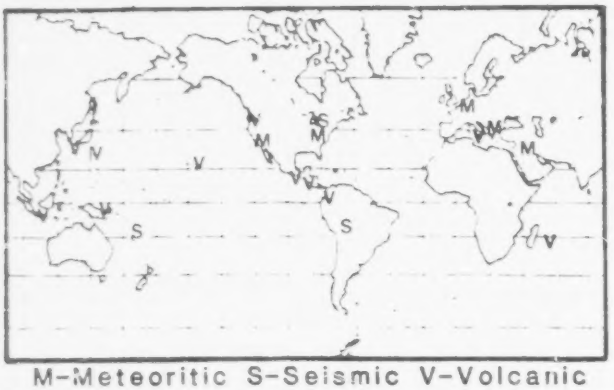

M-Meteoritic S-Seismic V-Volcanic

SEAN
Scientific Event Alert Network

BULLETIN

VOLUME 11, NO. 1, JANUARY 31, 1986

COMPLETED
ORIGINAL

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VOLCANIC EVENTS

Fukutoku-oka-no-ba Volcano, Volcano Islands, Japan (24.28°N, 141.52°E). All times are local (= GMT + 9 hours).

An eruption of Fukutoku-oka-no-ba submarine volcano built a small island in mid-January. Only milky blue discolored sea water was observed near the volcano on 16 January at about 1200. By 18 January at 2000, eruptive activity was frequent, producing a dark plume, seen from a fishing boat, that reached 3000-4000 m height. An hour later the plume was evident on an image from the Japanese GMS satellite. The next day at about 1630, airborne radar detected a plume rising to 4000 m above sea level. On 20 January at 0440, radar on the Japan Maritime Safety Agency's survey ship Takuyo showed an island-like image. A gray plume rose to 2000 m altitude at 0550.

A new island was recognized by observers on the Takuyo at 0630. A 50-m vent at the NW edge of the new island ejected plumes and sea water. Continuous observations were made until about 1000. The island was about 700 m long, 500 m wide, and 15 m high (figure 1). A vent near its E edge remained below sea level, ejecting black incandescent rocks as much as 10 m in diameter. Grayish brown pumice had drifted as much as 18 km NE from the vent. Discolored sea water surrounded the island and extended 22 km NE from the vent. The sea water was greenish near the island, gradually becoming greenish yellow or pale blue farther from the vent. At 1122 a dark plume containing incandescent rocks to 10 m in diameter rose 1200-1300 m above sea level; between 1250 and 1400 a vapor plume rose to 3000 m. There was a long, narrow zone of discolored water about 45 km long and 2-3 km wide. Between 1450 and 1550, explosions occurred at about 20-minute intervals, expelling dark plumes that rose about 1200-1700 m. Between 1600 and sunset, 90 weak to moderate explosions ejected plumes to 100-1000 m height. Volcanic flame was occasionally seen within dark plumes at night.

The next morning at 0800 explosions produced small plumes (less than 50 m high) at intervals of 1-2 minutes. At 1223, a large explosion was seen; volcanic flame reached 1500 m above sea level, roughly half of the plume's height. At 1300 the island was flat and crescent-shaped, covered with ash and pumice but no lava flow. The outer arc of the crescent was a portion of a circle about 700 m in diameter having a center that roughly coincided with the position of the active vent, which was about 300 m in diameter (figure 2). An area of thin yellow or green discoloration extended SSE to 2 km from the island. Pumice drifted E and S.

By the morning of the 22nd explosive activity had subsided; no plumes were seen for the rest of the month. Erosion of the shoreline of the new island was evident early the next day. However, at 1300 outflow of discolored sea water suggested that the submarine vent, 80 m in diameter, was still active about 400 m E of the island.

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Fukutoku-oka-no-ba Volcano (continued)

The island, covered with gray ash, was about 500 m in length and had a maximum width of 200 m. During the morning of 25 January, dense blue discoloration was seen around and E of the island and had drifted somewhat eastward, to about 9 km from the vent. On the 29th the island's size was estimated at about 600 m long, about 400 m wide and about 10 m high (this preliminary estimate does not necessarily indicate growth since the 23rd). Yellowish green discoloration extended as much as 38 km to the NE, and brown pumice was floating in lines near the island.

Between 20 December and 20 January, nearly 100 T-phase waves of moderate intensity were received by high-gain seismic stations at Rangiroa, Tuamoto Islands (about 9000 km SE of Fukutoku-oka-no-ba). J. M. Talandier noted that T-phase waves are characteristic of submarine eruptions, having shallow (ocean) depth. The origin of these waves was in the NW Pacific, and they may be related to the eruption of Fukutoku-oka-no-ba.

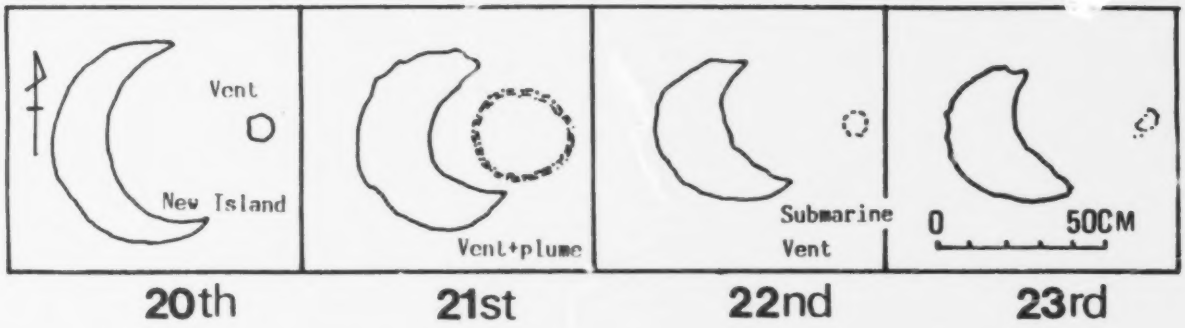

Figure 1: Sketch map of the new island and associated vent and plume 20-23 January, courtesy of the Japan Meteorological Agency.

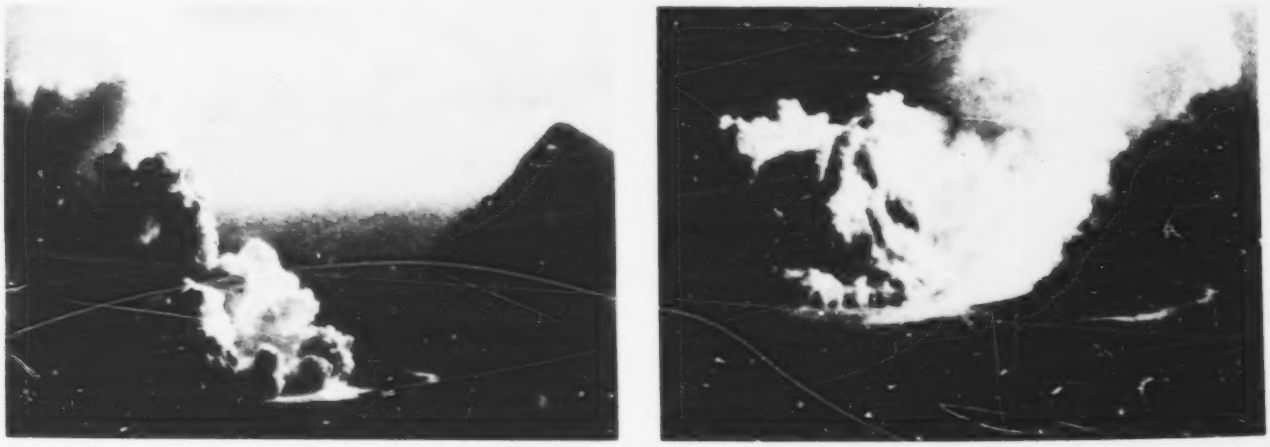

Figure 2: Photographs of the new island and eruption plume, taken by G. Iwashita, Office of Volcanic Observation, JMA, on 21 January at about 1400 (left) and 1600 (right). The conical island in the right background of the earlier photo is Minami Iwo Jima.

Discolored water has frequently been observed around Fukutoku-oka-no-ba in recent years. In an interview on a Japan Broadcasting Network newscast, Professor Kosaka of Okayama University reported that about 8 years ago a sonar survey from the

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Fukutoku-oka-no-ba Volcano (continued)

Tokyo Fisheries University's ship Seio-maru detected a seamount with a summit 40 m below sea level and roughly 150 m wide, beneath the discolored water zone at Fukutoku-oka-no-ba. Small islands were formed during the 1904-5 and 1914 eruptions, but did not persist after 1905 and 1916. An island was reported during an eruption on 24 December 1974, but was not visible the next day.

Information Contacts: Office of Volcanic Observation, Seismological Division, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan; J. M. Talandier, Laboratoire de Géophysique, BP 640, Papeete, Tahiti; NHK Japan Broadcasting Corporation, Tokyo, Japan.

Sakurajima Volcano, Kyushu, Japan (31.58°N, 130.67°E). All times are local (= GMT + 9 hours). The following is from the Japan Meteorological Agency.

"Frequency of explosions at the summit of Minamidake further increased in December when a total of 75 explosions were recorded with at least one almost every day (tables 1 and 4). A distinguishing characteristic of December volcanic activity was the reciprocal appearance of earthquake swarms and vigorous summit eruptions. Swarms of earthquakes were recorded on 1, 2, 3, 4, 8, 14, 17, 20, 21, 23, 26, 27, and 31 December, in almost every case the days of fewer explosions (except for 2, 3 and 30 December). Even on those 3 days, swarm activity occurred before or after the phase of summit explosive activity. This fact suggests that magma had been repeatedly and effectively transported in the conduit through the month.

"On 3 December at 0103, an explosion was accompanied by an airshock, strong enough to break 188 windowpanes in the city of Kagoshima, about 10 km W of the crater. Another strong shock on 19 December at 0546 broke 85 windowpanes and a car windshield in Ushine city, about 13 km ESE of the crater (table 2). In both cases, the presence of an inversion layer at 1000 m altitude (3 December) and 1500 m altitude (19 December) seemed to amplify the airshocks.

"Lapilli also caused some damage: a windshield on a car was broken at Kurokami (4.5 km E of the crater) on the 5th, and at the volcano's SW foot on the 16th and 19th. An explosion on 19 December at 1810 ejected incandescent rocks and one of them made a 1-m diameter hole near an inhabited house at Arimura (3 km SSE of the crater).

"In January, the monthly number of explosions declined to 35 (table 1) and seismic activity also declined. Lapilli from an explosion on 1 January at 1158 broke the windshields of 6 cars at the SW foot.

TABLE 1: Explosions at Sakurajima

Date: Dec.	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	18	19	20	21	24	25	26	27	30	31
Number	2	3	6	3	5	5	3	1	2	4	4	3	2	2	6	3	3	1	1	5	1	2	1	3	4

Date: Jan.	1	2	4	7	9	10	11	12	13	14	15	16	18	19	21	22	23	24	25	26	27	28	31
Number	4	2	2	2	1	1	1	2	2	3	1	1	2	1	1	1	2	1	1	1	1	1	1

TABLE 2: Five Major Episodes of Damage to Windows by Airshocks

3 Dec. 1985	Kagoshima City (10 km W), base of volcano	188
17 May 1976	Tarumizu City, Furusato (3 km S)	162
30 Nov. 1977	Arimura (3 km SSE), Furusato (3 km S)	102
19 Dec. 1985	Tarumizu City	85
1 Feb. 1977	Tarumizu City	65

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Sakurajima Volcano (continued)

"At the JMA Kagoshima Observatory, 474 explosions were recorded in 1985 and cumulative ashfall was 15908 g/m², the largest since the summit eruptive activity began in 1955 (table 3)."

TABLE 3: Number of Explosions per Year at Sakurajima, 1955-1985

Year	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Number	6	115	57	83	109	414	196	89	136	88	29	44	127	37	22	19

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Number	10	108	144	362	199	176	223	231	149	277	233	233	413	332	474

TABLE 4: Six Largest Monthly Explosion Totals

Month	June 1984	Oct. 1960	Dec. 1985	Feb. 1983	Sep. 1960	May 1980
Number	93	80	75	73	69	69

Information Contact: Volcanological Center, Seismological and Volcanological Department, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Stromboli Volcano, Lipari Islands, Italy (38.79°N, 15.21°E). All times are local (= GMT + 1 hour). The following is a report from Mauro Rosi and Alessandro Sbrana.

"On 6 December at 0745 an eruptive crisis with lava flow emission started at Stromboli, interrupting a 10-year period of persistent mild explosive activity during which liquid lava was constantly in the summit craters. Inception of the eruption was accompanied by a violent explosive phase and by the opening of a trough a few tens of meters wide on the NE margin of the crater platform. The newly formed eruptive trough, about 100 m long, developed from the easternmost vent of the main crater platform (825 m altitude) roughly northeastward down to an altitude of 680 m (figure 3). During the initial explosive phase, which lasted about 1.5 hours, ash clouds rich in steam rose to an altitude of 2-3000 m. At about 0815, a small nuée ardente descended the NW flank's Sciara del Fuoco (near the Fili del Fuoco side), reaching the sea. The explosive activity was mainly confined to the newly formed trough, which was probably widened by ejection of abundant old and fumarolically altered material. The first emission of a lava flow was from a temporary vent a few tens of meters higher than the eventual main eruptive vent, preceding or accompanying the explosive phase. The first lava flow descended toward the easternmost edge of the Sciara, forming a small lava field (at the foot of Bastimento rock). Later that morning, the lava vent was displaced northward to an elevation of about 680 m because of further collapse of the eruptive trough. From this point, a second lava flow started to descend the 40° steep slope of the Sciara del Fuoco, reaching the sea at about 1100.

"During the following days, the lava front advanced a few tens of meters into the sea, forming a small peninsula at the NE end of the Sciara del Fuoco. Advance of the lava flow into the sea was frequently accompanied by secondary phreatic explosions and strong steaming. The lateral drainage of the degassed lava was followed by a drop of the lava level in the upper craters, changing their activity from lava fountains (5 December) to rhythmic puffs of ash clouds and continuous steaming.

"A visit to the summit on 8 December revealed a thin ashfall cover containing millimeter-sized accretionary lapilli deposited during the initial phreatomagmatic explosive phase. Outpouring of lava continued through December and January, with an average decline in lava output and a tendency to accumulate materials on the eastern side of the Sciara del Fuoco. Lava was still emerging on 27 January.

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Stromboli Volcano (continued)

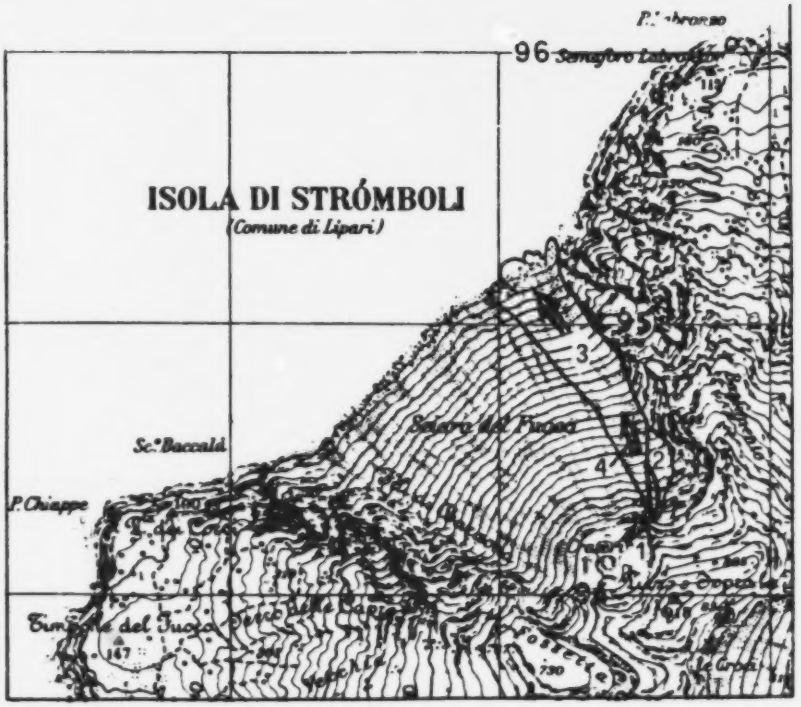

Figure 3: Map of the summit and NW flank of Stromboli, courtesy of Mauro Rosi and Alessandro Sbrana, showing the new eruptive trough (1), the initial lava flows (2), the 6 December-1 January lava flows (3), and the path of the 6 December nuée ardente (4). Contour interval is 20 m.

"Preliminary seismic investigations (Biviano et al., 1985) indicated that no relevant variations occurred in the 3 months preceding the eruption. An isolated event (M>2.5) located a few km below the volcano was recorded on 18 November, about 2 weeks before the eruption. Microseismicity related to the very shallow explosivity of the volcano revealed a weak tendency to increase as the eruption approached. Preliminary analysis of the lava emitted in the first few days of the eruption indicated that the rock is a silica undersaturated shoshonitic basalt (SiO_2 49.5%, Ne 1.1), containing phenocrysts of olivine, clinopyroxene, and plagioclase very similar to those erupted in historic time at Stromboli.

"The 6 December phenomena and their precise timing were reconstructed from eyewitness observations and photographs. Field investigations were performed 7-14 December and 29 December-4 January by Mauro Rosi and Alessandro Sbrana (University of Pisa) and Giovanni Frazzetta (Istituto Internazionale di Vulcanologia, Catania). Preliminary information on seismicity was provided by G. Neri (IIV, Catania) and extracted from Biviano et al., 1985. XRF analysis of major elements was performed at the University of Pisa (table 5).

References: Biviano, A., Di Prima, S., Falsaperla, S., Marturano, M., Neri, G., Pellegrino, A., and Velardita, S., 1985, Relazione Informativa sull'attività Sismica a Stromboli; internal report to the National Group of Volcanology, CNR.

Capaldi, G., Guerra, I., Lo Bascio, A., Luongo, G., Rapolla, A., Scarpa, R., del Pezzo, E., Martini, M., Ghiara, M. R., Lirer, L., Munno, R., and La Volpe, L., 1978, Stromboli and its 1975 Eruption; Bulletin Volcanologique, v. 41, no. 3.

Information Contacts: Mauro Rosi and Alessandro Sbrana, Dipartimento di Scienze della Terra, University of Pisa, Via S. Maria 53, 56100 Pisa, Italy.

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Stromboli Volcano (continued)

Table 5

	1975 sc	1975 la	1976 sc	1985 ST-4	1985 ST-5
SiO_2	50.19	50.36	50.81	49.68	49.36
TiO_2	.80	.92	.75	.95	.94
Al_2O_3	16.91	16.19	16.83	18.68	18.68
Fe_2O_3	2.36	2.90	2.50	3.06	2.91
FeO	5.80	5.26	5.81	4.88	5.31
MnO	.15	.17	.15	.16	.16
MgO	5.54	5.92	6.06	5.00	5.41
CaO	11.01	10.94	9.94	10.61	10.85
Na_2O	3.38	3.37	3.40	3.05	2.92
K_2O	2.49	2.50	2.64	2.24	2.11
P_2O_5	.40	.40	.40	.48	.44
CO_2	-	-	-	-	-
H_2O	.20	.40	.14	1.20	.91
Total	99.23	99.33	99.43	100.00	100.00

Table 5: XRF analysis performed at the Dipartimento di Scienze della Terra, University of Pisa on 6 December 1985 lava (samples 1985 ST-4 and 5). For comparison, analyses (from Capaldi et al., 1978) of lava and scoria from the 1975 eruption (1975 sc and la) and scoria from 26 April, 1976 are shown in columns 1-3.

Campi Flegrei, S Italy (40.83°N, 14.14°E). The following is from Roberto Scandone.

"Since January 1985, there has been no detectable seismic activity at Campi Flegrei. The last magnitude 4 earthquake occurred in December 1984. The most notable fact is that since January 1985 the ground has been subsiding at a mean rate of about 1 cm per month without any seismic activity (figure 4). The pattern of ground deformation during the crisis of 1982-1984 was similar to that during 1970-1972. The main difference is that the latter crisis was accompanied by moderate seismic activity during the uplift phase. Gas monitoring of fumaroles in Solfatara Crater showed no significant changes in the past year.

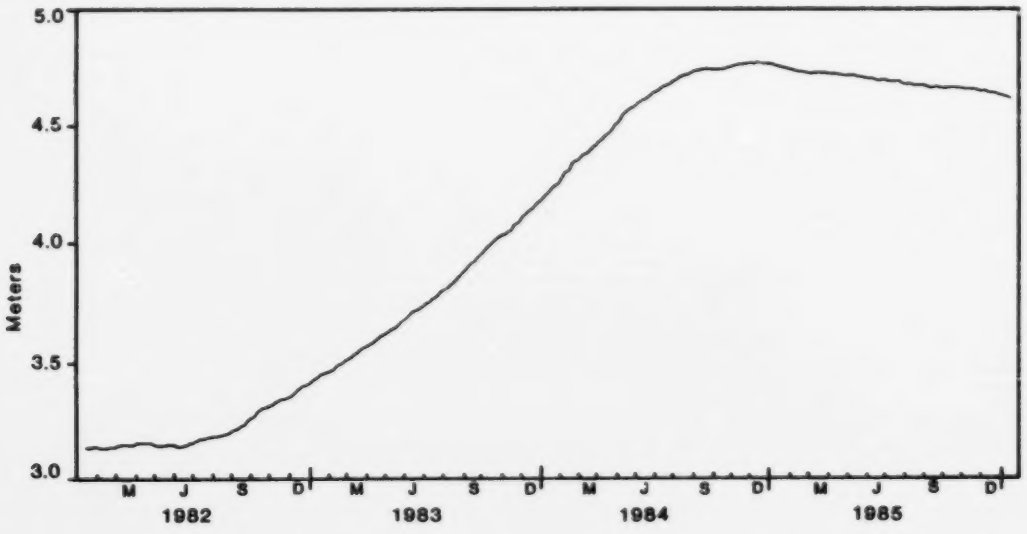

Figure 4: Ground movements measured by the tide gauge in Pozzuoli Harbor, January 1982-December 1985, courtesy of Roberto Scandone.

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Campi Flegrei Volcano (continued)

"During the past year, people from Pozzuoli have slowly been moving back into the town. The new settlement on the NW side of the caldera has almost been completed, but it is not certain that all of the people evacuated from the town will move in. The fears of an impending eruption are already gone, and the interest of the media has vanished."

Information Contacts: Giuseppe Luongo and Roberto Scandone, Osservatorio Vesuviano, Largo San Marcellino 10, 80138 Napoli, Italy; Franco Barberi, Dipartimento di Scienze della Terra, University of Pisa, Via S. Maria 53, 56100 Pisa, Italy.

Etna Volcano, Sicily, Italy (37.73°N, 15.00°E).

Seismicity has continued since Etna's SE flank fissure eruption in late December (see last month's Bulletin). The following is from Romolo Romano.

"Beginning 1 February, a series of shocks occurred on all of the flanks of Etna (see table 6 for some of the largest events). The events with the most energy occurred 1 and 2 February about 15 km SE of the summit (in the Dagala zone, in the area of Santa Venerina and Linera), with magnitudes between 3.0 and 3.6 and depths within 1 km. During the week, 50 shocks were also recorded by instruments, mainly on the E flank."

TABLE 6

Date	Location (& Distance from Summit)	Magnitude	Depth
3 Feb.	E of S. Pizzuta	3.0	1 km
4 Feb.	between Linera and Guardia Mangano (16 km SE)	2.5	1 km
5 Feb.	E of Mt. Pomiciaro (15 km NE)	3.2	16 km
6 Feb.	N flank, E of Malvagna	3.1	4 km
7 Feb.	between Mt. Pomiciaro & Linguaglossa (15 km NE)	3.0	16 km

Information Contact: Romolo Romano, Istituto Internazionale di Vulcanologia, Viale Regina Margherita 6, 95123 Catania, Italy.

Piton de la Fournaise Volcano, Réunion Island, Indian Ocean (21.23°S, 55.71°E). All times are local (= GMT + 4 hours). The following is from the Observatoire Volcanologique du Piton de la Fournaise.

"The eruptive episode that began on 29 December (see last month's Bulletin) inside the central (Dolomieu) crater was still in progress on 31 January. The main cone, in the SW part of the crater (figure 6), reached a height of 40 m. Explosive activity was less important than during the first few days of the eruption. The vent emitted lava fountains to 20-50 m above the crater rim during the first weeks of January; afterward, fountains were limited to 15 m height.

"More than 95% of the crater floor has been covered by the new lava flow; maximum thickness was 20-25 m in the NE part of the crater. The total volume of the emitted lavas was approximately 7 x 10^6 m^3 as of 30 January. All the lavas are aphyric basalts.

"Tilt stations around the summit craters indicated a general deflation (15-70 microradians) after the beginning of the eruption. No significant movement was recorded between 8 and 22 January. The plume was still very rich in SO_2 and numerous fumaroles were found at the base of the main cone on top of the lava tubes.

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Piton de la Fournaise Volcano (continued)

"The seismic station located close to Bory crater (just W of Dolomieu crater) was saturated during the whole month. The Soufrière station (300 m NNW of Dolomieu crater) received significant signals from the tremor. This tremor has begun to decrease since 20 January on all stations except Bory. Major tremors affected the walls of the Dolomieu crater, causing collapse and forming numerous cracks on the S rim and the rim between Bory and Dolomieu.

Figure 6 (right): Sketch map of the summit caldera region of Piton de la Fournaise after Blum, P., Gaulon, R., Lalanne, F., and Ruegg, J., 1981, Sur l'evidence de Precurseurs de l'eruption du Piton de la Fournaise a la Réunion (Fevrier 1981); Comptes Rendus Acad. Sci. Paris, v. 292, serie II, p. 1449-1455.

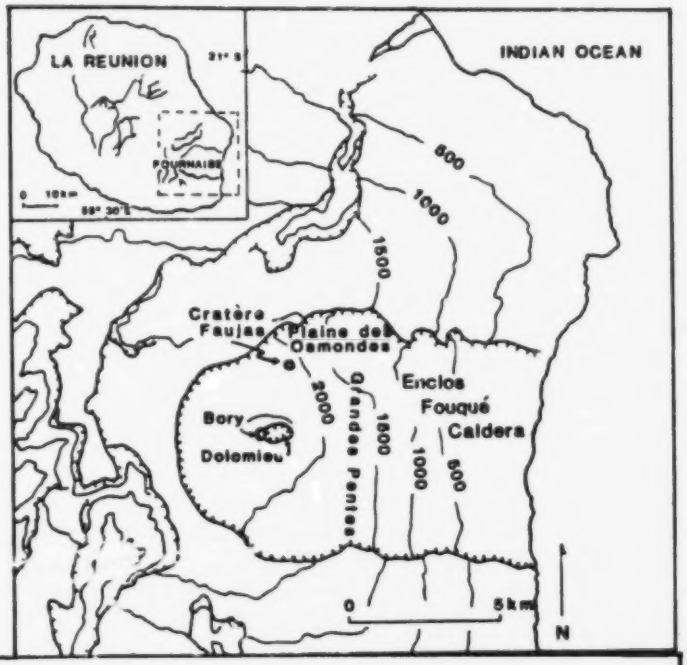
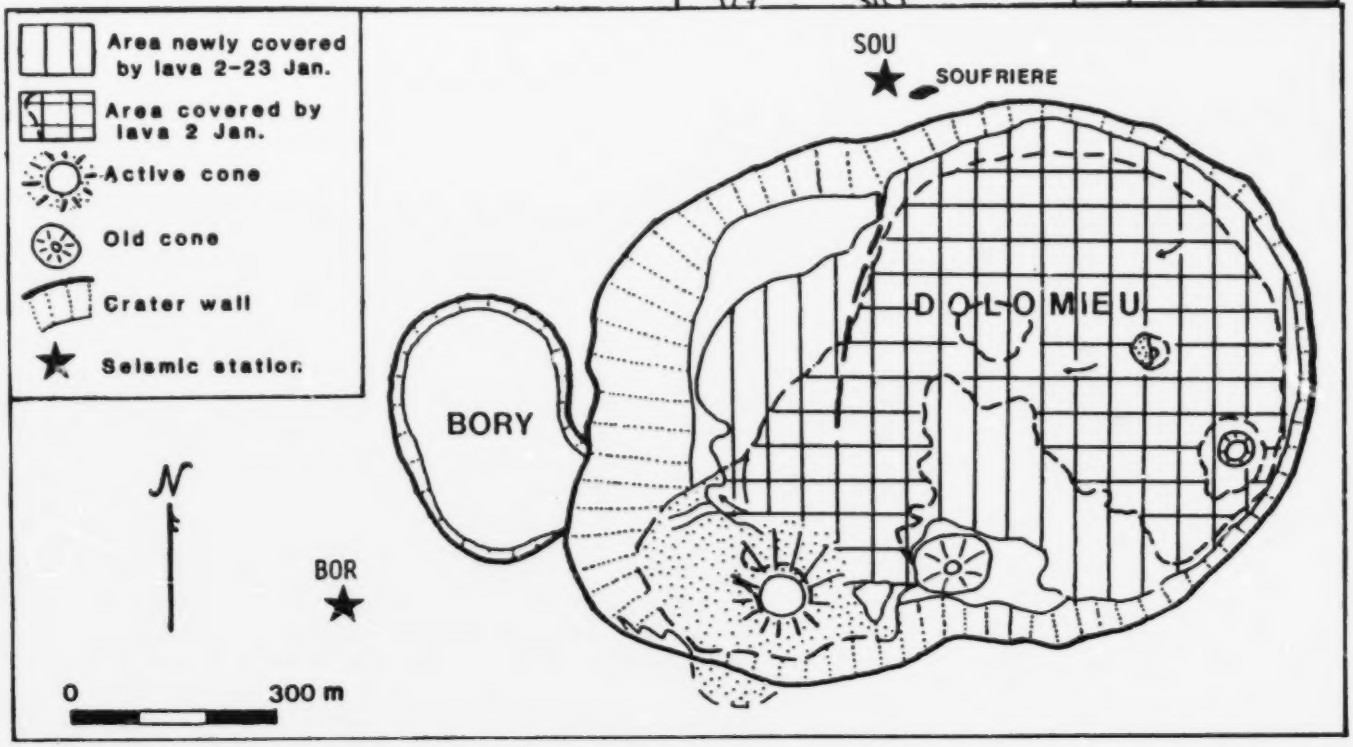


Figure 7 (below): Map of the summit craters of Piton de la Fournaise as of 23 January, courtesy of the Observatoire Volcanologique du Piton de la Fournaise. The area covered by lava on 2 January (see map in last month's Bulletin) is shown by a cross-hatched pattern.



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Piton de la Fournaise Volcano (continued)

Information Contacts: Hughes DeLorme and Jean-François DeLarue, Observatoire Volcanologique du Piton de la Fournaise, 14 R.N. 3, 27ème km, 97418 La Plaine des Cafres, Réunion Island; P. Bachelery, Laboratoire de Géologie, Université de la Réunion, Réunion Island.

Ruiz Volcano, Colombia (4.88°N, 75.37°W). All times are local (= GMT - 5 hours).

Seismicity and deformation continued through early February, but there had been no eruptive episodes since the minor explosive activity on 4 January (see last month's Bulletin). Plume heights varied from 100 m to about 1000 m above the summit (often in a single day), partly dependent on the amount of rainwater accumulated in the crater. Weak ash emission occurred on some days, falling near the crater.

After the 4 January ash emission, about 4 mixed-frequency seismic events were recorded per day, declining to fewer than 1 per day since 1 February. Between mid-January and mid-February, there were normally about 10 high-frequency events per day, with 2 small crises on 8 and 14 February of about 20 events each (magnitudes less than 1). The low-frequency seismicity also registered about 10 events daily without significant variations. Depths were between 2 and 6 km below a datum at 3.8 km above sea level, with epicenters typically less than 2 km from the crater, closer than in December. In early February, events were concentrated in the NE part of the volcano.

An electronic tilt station W of the crater measured inflation values of the order of 0.5 microradians per day until the end of January, then dropped to 0.2-0.3 per day, while deformation on other flanks remained at lower rates (less than 0.1 microradian). A deformation event that started 18 January was measured by continuously recording tiltmeters 2 and 5 km NW of the summit and by EDM stations radiating W from the summit. About 20-25 mm/km of inflation accumulated before the episode ended 4-5 days later. Another small inflation episode was in progress on 13 February, totaling about 8 mm/km at a reflector about 4 km NE of the summit.

By February, rates of fissure displacements in the summit glaciers had slowed by as much as an order of magnitude, to millimeters or occasionally centimeters per day. Increased melting was observed but attributed to sunnier weather. Melting of ice caused buckling of overlying tephra layers that were as much as 6 m thick near the summit, producing features reminiscent of tumuli that form on top of block lava flows.

An improved alert system and additional hazard study has permitted some of the persons that had remained evacuated since 4 January to return to their homes.

Information Contacts: Isabel Mejía and Eduardo Parra, Comité de Estudios Vulcanológicos, 11° Piso, Edificio Londoño, Manizales, Colombia; Arnold Okamura, USGS Hawaiian Volcano Observatory, P. O. Box 51, Hawaii National Park, Hawaii 96718 USA.

Popocatépetl Volcano, Central Mexico, (19.02°N, 98.62°W).

The following is a report from the Universidad Nacional Autónoma de México.

"Members of the Mountain Climbers Group of the National University of México decended into the summit crater (elliptical shaped, 650 m x 450 m) of Popocatépetl 25-26 January. The lower part of the main crater rim was 5250 m above sea level and the crater was some 250 meters deep. On its E floor there was a smaller circular crater about 200 m in diameter and 50 m deep with a small, roughly circular lake about 40 m in diameter and 10 m deep. The water was warm (29°C) and very clear with

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Popocatépetl Volcano (continued)

a greenish color. This small lake is not permanent and its dimensions are season-dependent. The main crater floor appeared somewhat changed since a previous visit in 1978, when the rim of the interior crater was at a lower level. On the bottom of both the main and inner craters were many small fumaroles with sulphur deposits around them. The temperatures of 3 fumaroles sampled in the bottom of the inner crater were in the range 97°-99°C. In the E inner wall of the small crater were several fumaroles with vents that appeared to have greater activity. Their inaccessibility made it impossible to measure their temperatures but during the night they had a reddish glow, suggesting much higher temperatures. This kind of glow has not been reported inside the crater since 1938."

Eighteen eruptions have been reported from Popocatépetl in the past 600 years, the most recent in 1942-3. Most were apparently characterized by weak summit explosive activity.

Information Contacts: Hugo Delgado Granados and Servando de la Cruz-Reyna, Instituto de Geofísica, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México D. F., México; Manuel Casanova, D.G.A.D. Y.R., Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 Mexico D.F., México.

Tacaná Volcano, México/Guatemala border (15.13°N, 92.10°W). All times are local (= GMT - 6 hours).

A series of shallow earthquakes centered within 20 km of Tacaná began 15-16 December and was continuing in early February. On 19 December, a magnitude 5 earthquake centered near Ixchiguan at 15.18°N, 91.99°W (about 15 km ENE of the volcano) caused minor damage to 60 adobe houses and a school built of reinforced concrete. This event was followed by a series of aftershocks that had ended by 30 January.

Geologists from the Universidad Nacional Autónoma de México visited the volcano in late January, finding no evidence of increased volcanic activity. A temperature of 9°C was measured at 20 cm depth in the summit lava dome. At Aguas Calientes hot springs at the foot of the volcano, water temperatures were 50°C; temperature and water outflow rate have apparently remained unchanged for 50 years. A portable seismometer placed on the volcano's summit for 2 hours and at its base for 4 hours on 26 January recorded small earthquakes but no harmonic tremor.

On 3 February, another magnitude 5 earthquake was recorded in the same area as the 19 December event. Moderate damage occurred to 500 adobe houses in the villages of Ixchiguan (18 km ENE of the summit of Tacaná), Calapte, Toacá (13 km NE of the summit), Sanajaba, Sibinal (7 km NE of the summit), Vega del Volcán, María Cecilia, and Toaman. Shocks of magnitudes 4.2, 3.0, and less than 3.0 followed. Some of the earthquakes had a NW-SE alignment in the Toacá-Ixchiguan area. Volcanic earthquakes were felt in Sibinal and rumbling was heard at the base of the volcano.

A joint INSIVUMEH/Universidad Nacional Autónoma de México team recorded only volcanic earthquakes 3-7 February. However, harmonic tremor began to appear on 8 February. Harmonic tremor strengthened the next day and seismicity was migrating around the volcano.

There have been no certain historic eruptions of Tacaná. Although several episodes of plume emissions and/or explosions have been reported since the mid-19th century, none is well-documented.

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Tacaná Volcano (continued)

Information Contacts: Servando de la Cruz-Reyna, Instituto de Geofísica, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México D.F., México; Eddy H. Sanchez B., Carlos Martínez, and Edgar R. Quevec, INSIVUMEH, 7a. Avenida 14-57, Zona 13, Guatemala City, Guatemala.

San Miguel Volcano, El Salvador (13.44°N, 88.27°W).

Weak steam and ash emission accompanied by frequent small earthquakes began in November and were continuing in early February. The eruption deposited a thin layer of ash near the summit. Geologists installed a telemetering seismometer about 1 km from the summit, recording about 200 discrete microseismic events per day from November through much of January. By the end of January, seismic activity had declined somewhat, to 100-120 events per day.

Information Contacts: José González and Salvador Jesus, Departamento de Sismología, Centro de Investigaciones Geotécnicas, Apartado Postal 109, San Salvador, El Salvador; David Harlow, U. S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025 USA.

Kilauea Volcano, Hawaii, USA (19.42°N, 155.27°W). All times are local (= GMT - 10 hours).

Kilauea entered its fourth year of activity in January with the 40th and 41st episodes of the East Rift Zone eruption. Episode 40 began 1 January at 1309 and lasted 13.5 hours. It produced a lava flow about 9 km long that overlies earlier flows and reached the NE corner of Royal Gardens Subdivision (see figure 7). The volume of this flow was 11.6 x 10^6 m^3.

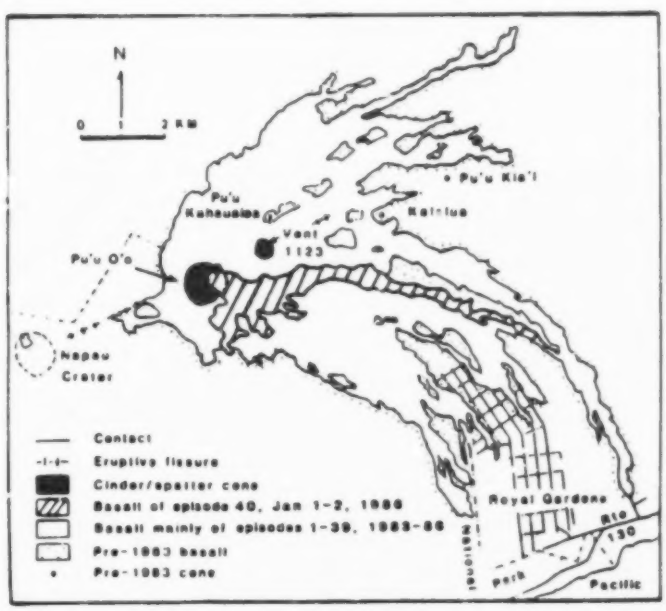

Figure 7: Lava flows produced by Kilauea's East Rift Zone eruption since January 1983. Episode 40 flows are shown by a separate pattern.

When episode 41 began on 27 January, after only 25 days of repose, only 9.5 microradians of the deflation that occurred during episode 40 had been recovered (figure 8). Because of inclement weather, it was not possible to establish a precise start time from time lapse film but the first lava spillover from the crater into the flow channel was reported by a helicopter pilot on 26 January at 1240. A field crew

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Kilauea Volcano (continued)

that was at Pu'u O'o on 27 January from 1230 to 1600 observed almost continuous small spillovers. Deflation began on 27 January at 1900 and totaled 16.5 microradians by the end of episode 41. Harmonic tremor started at 2030, increased at 2035 and continued at high amplitude until 0737 the next morning when lava production stopped. Lava flows extended 6.7 km to SE, to within 400 m of the NE corner of Royal Gardens Subdivision. By the end of January tilt had recovered 8.4 microradians.

Information Contacts: Christina Heliker, George Ulrich, Robert Koyanagi and Ron Hanatani, USGS, Hawaiian Volcano Observatory, P. O. Box 51, Hawaii National Park, Hawaii 96718 USA.

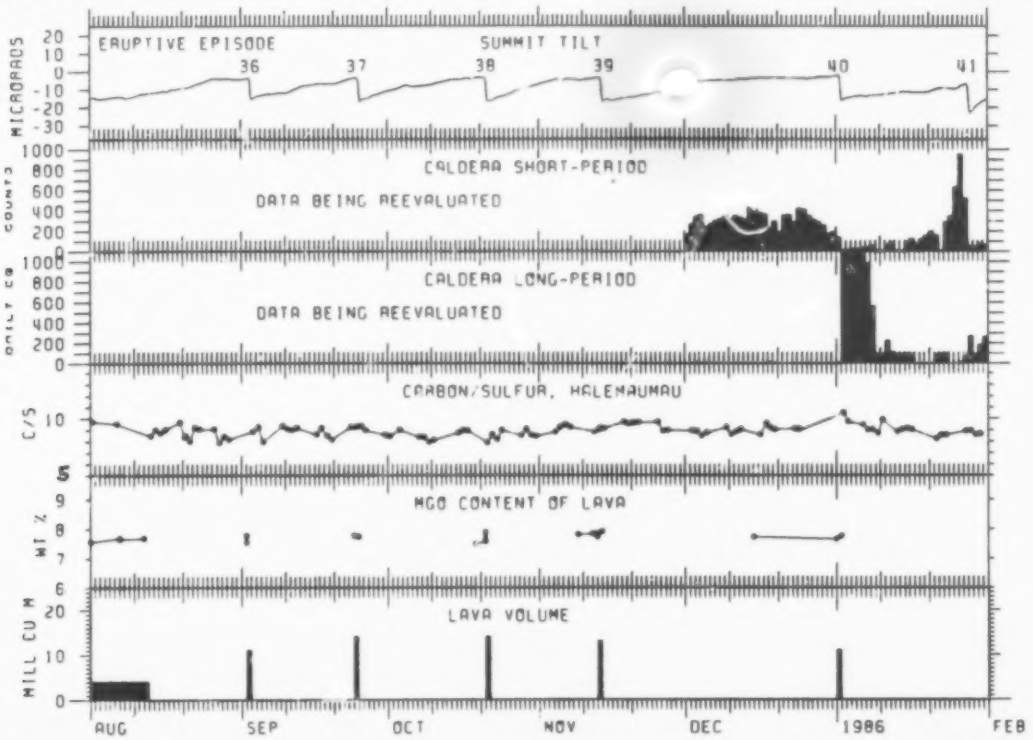

Figure 8: Six-month summary of Kilauea activity, showing summit tilt, caldera short- and long-period earthquakes, carbon/sulfur ratios of summit (Halemaumau) gases, MgO content of lava collected during and between eruptive episodes, and lava volumes. Lava volume for episode 41 has not yet been calculated.

Mt. St. Helens Volcano, Cascade Range, S Washington, USA (46.20°N, 122.18°W). All times are local (= GMT - 8 hours).

Seismicity, deformation rates, and SO_2 emissions remained at background levels through early February. Deformation on the dome averaged less than 1 mm per day; two successful SO_2 flights in January showed an average emission of 68 $\pm$ 22 metric tons per day. Seismometers recorded 27 surface events, all attributed to rockfalls. There was no seismic evidence of energetic steam emission.

On 30 December at 1600, seismometers in the crater began to record a sequence of earthquakes centered on the lava dome. For the next 1.75 hours, 100 individual earthquakes were recorded above a "tremor-like" background signal with frequencies 3 to 4 times higher than that of harmonic tremor. Approximately an hour after the

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Mt. St. Helens Volcano (continued)

onset of seismicity, a gas emission event was detected by the atmospheric hydrogen sensor located on the dome. H_2 was released in one large pulse lasting about an hour, followed by several smaller pulses.

CVO scientists interpret the seismicity coupled with H_2 degassing as evidence for sudden contact of groundwater with magma. The resulting pressure change may have produced microfractures in overlying crustal material, which in turn allowed the release of gas to the atmosphere. The background "tremor-like" signal (acoustic emission) is believed to be associated with moving gases rather than the moving magma associated with harmonic tremor.

Information Contacts: Kenneth McGee, Eliot Endo, Eugene Iwatsubo and Steven Brantley, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, Washington 98661 USA; Chris Jonientz-Trisler, Geophysics Program, University of Washington, Seattle, Washington 98195 USA.

Sangeang Api Volcano, Lesser Sunda Islands, Indonesia (8.18°S, 119.06°E). All times are local (= GMT + 8 hours). This and the Tangkubanparahu report are from Adjat Sudradjat.

"Activity started on 30 July from the main summit crater (Doro Api, 1949 m above sea level). At about 0900 a thick plume rose to 3500 m height. The eruption continued with explosions at 1130 (6500 m), 1320 (6500 m) and 1800 (1500 m). About 2 mm of ash fell in Bima, 50 km SW of the volcano. Between then and 5 August explosions occurred every 30-60 minutes. Black plumes reached 2000-2500 m height. On 6 August at 1939 lava was observed flowing W from Doro Api crater. At the end of September the lava flow had advanced about 4750 m. Numerous explosions took place from September to November producing columns about 400-500 m high. On 17 November an explosion ejected incandescent lava fragments to about 250 m height and a plume rose to 1200 m above the crater. During December and January, gas explosions, sometimes accompanied by ejection of incandescent lava fragments, averaged about 80 events per day. The 1242 inhabitants of the island were evacuated to the main island of Sumbawa. There were no casualties."

Information Contact: Adjat Sudradjat, Director, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Tangkubanparahu Volcano, West Java, Indonesia (6.77°S, 107.60°E).

"In November, Tangkubanparahu showed increased activity with strong gas emission, thick white solfataric fume, and increased temperature at Kawah Baru, a small vent on the W side of the summit crater. Temperatures, normally 95-97°C, rose to 141°C on 30 November, increased progressively to 173°C on 3 January, then slowly decreased. At the end of January the temperature was 158°C. Seismic observations November-January showed no signs of changes. The average number of volcanic earthquakes was 2 per day."

Information Contact: Same as for Sangeang Api.

Papua New Guinea

The following is from the Rabaul Volcano Observatory; no unusual activity was reported at Bagana. All times are local (= GMT + 10 hours).

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Papua New Guinea (continued)

Rabaul Caldera, New Britain Island (4.27°S, 152.20°E).

"Seismicity, although still at a very low level, showed a slight increase in January with 72 events recorded, compared to 48 in December. The total might have been higher if 2 of the 3 seismic stations closest to Greet Harbour had been functioning. Ground deformation measurements show that the weak deflationary trend observed late in 1985 appears to have stopped, with possible local reversals.

Langila Volcano, New Britain Island (5.53°S, 148.42°E).

"Moderate activity, which had begun in late December 1985 (see last month's Bulletin), continued for the first half of January. Numerous explosions from Crater 2 were seen, and there were daily reports of rumbling sounds at the observation post 10 km N of the summit. A light ashfall was reported at the observation post on 3 January. Occasional incandescence from Crater 2 was seen at night until the 13th. Low-frequency harmonic tremor was recorded on the 2nd, 3rd, and 7th. Numerous explosions (3 to 30 per day) were recorded throughout January.

Ulawun Volcano, New Britain Island (5.04°S, 151.34°E).

"In early January, seismicity at Ulawun was still declining (100-200 events per day), following the eruption in November 1985 (see SEAN Bulletin v. 10, no. 11). On 22 January seismicity increased slightly to 300-500 events per day for 4 days then returned to previous levels. No significant visible activity was reported.

Manam Volcano, off the N coast of New Guinea (4.10°S, 145.06°E).

"Activity continued at a low level. There were daily reports of weak to moderate gray and brown emissions from the main and S craters. Frequent light ashfalls were reported from around the island throughout January. Seismicity remained at non-eruptive levels."

Information Contact: P. Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Atmospheric Effects

From Tsukuba, Japan (36.2°N, 140.1°E), Sachiko Hayashida reported that the aerosol layer detected at 18 km altitude on 11 and 12 December (see last month's Bulletin) was probably present on 1 December, but with a scattering ratio of only about 1.3 (figure 12). On 6 January, another aerosol layer was observed at about 22 km altitude. The peak scattering ratio of this layer increased to about 2.8 on 9 and 10 January. Aerosols were concentrated in a layer about 1 km thick. The 14 Janaury profile showed a decrease in peak scattering ratio to about 1.6. At Mauna Loa, Hawaii (19.5°N, 155.6°W), lidar profiles showed an increase in aerosol concentrations through January as the layer centered at about 20 km altitude strengthened (figures 10-11 and table 7). Only remnants of El Chichón's 1982 eruption cloud were detected by lidar at Garmisch-Partenkirchen, Germany (47°N, 11°E) through 4 January. The next measurement, on 21 January, showed new layers centered at 18.6 and 21 km altitude. Data on 22 and 26 January continued to show new aerosols, centered at 18 and 17.4 km.

NASA's SAGE II/SAM II/Polar Stratospheric Cloud mission 7-22 January included airborne lidar measurements from near Hampton Virginia to 77°N. Initial data at 42.5°, 67.5°, and 76.5°N (between Hampton and Thule Greenland) 8-14 January showed relatively

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Atmospheric Effects (continued)

low backscattering ratios. However, during flights on 16, 21, and 22 January that penetrated the circumpolar vortex wind system, lidar detected strong fresh-looking aerosol layers about 2.5-3 km thick, centered at 18-20 km. Possible sources of the strong layers included the Kliuchevskoi eruption (see SEAN Bulletins v. 10, nos. 11-12) or remnants of the 1982 El Chichón cloud. After exiting the circumpolar vortex at about 76.8°N, 108°W on 16 January, backscattering ratios dropped sharply. NASA's SAGE II satellite detected aerosol concentrations that were enhanced 10 times or more above background on 4 and 6 December at 20.9°N and 1.3°N.

On 18 January, balloon-borne instruments over Laramie, Wyoming (41°N, 105.5°W) detected the first enhancement of optically active aerosols (radius > 0.15 microns) thought to have been produced by the 13 November eruption of Ruiz Volcano. A concentration of about 5/cm³ above a background of 1.8/cm³ was measured at 17 to 19 km (figure 9). No other major stratospheric perturbations have been observed in this component at Laramie since the eruption of El Chichón in 1982. Flights on 10 January and 3 February showed smaller increases in optically active particles.

Enhanced concentrations of condensation nuclei (CN, radius > 0.01 microns) were also measured on 18 January between 16 and 19 km altitude, peaking at 100/cm³ as compared to a background of 20-30/cm³. Figure 9 illustrates this increase and includes the profile for 5 December, when the first lower stratospheric CN perturbation was observed over Laramie since the eruption of El Chichón. This CN enhancement is thought to be caused by aerosols from the 13 November eruption of Ruiz, but increases observed at about 25 km altitude on 3 February are interpreted as having been produced by evaporation and recondensation of older aerosols in association with a stratospheric warming event at high northern latitudes.

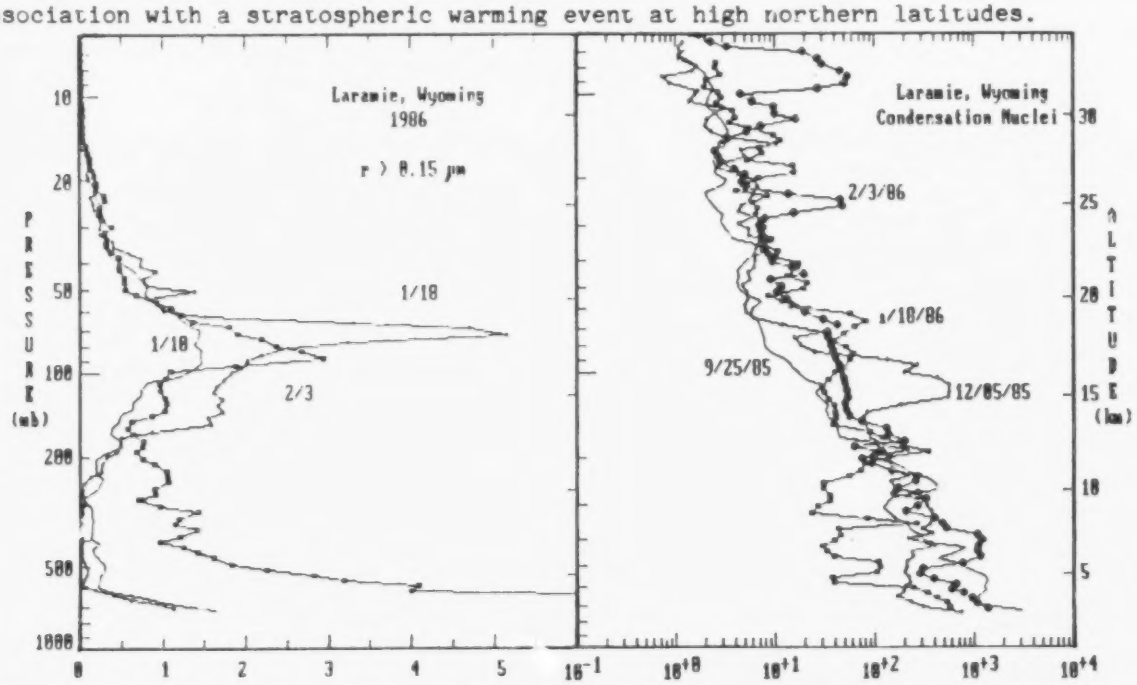

Figure 9: Aerosols collected by balloons launched from Laramie, Wyoming (41°N, 105.5°W) in late 1985 and early 1986: left, concentration of optically active aerosols (radius > 0.15 microns); right, concentration of condensation nuclei (radius > 0.01 microns).

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Atmospheric Effects (continued)

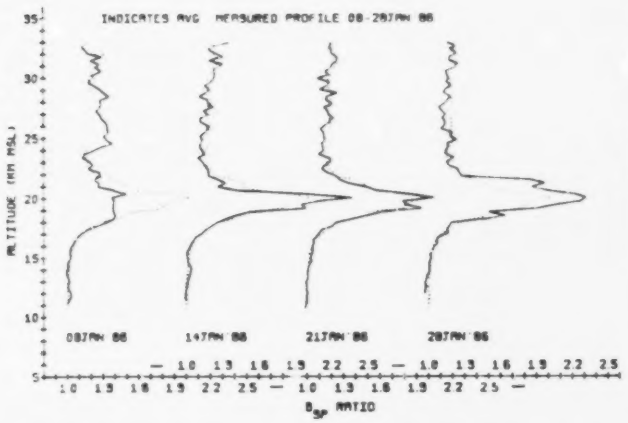

Figure 10: Lidar profiles from Mauna Loa, Hawaii (19.5°N, 155.6°W), 8-28 January, courtesy of Thomas DeFoor. The dotted line superimposed on each profile represents the average January data.

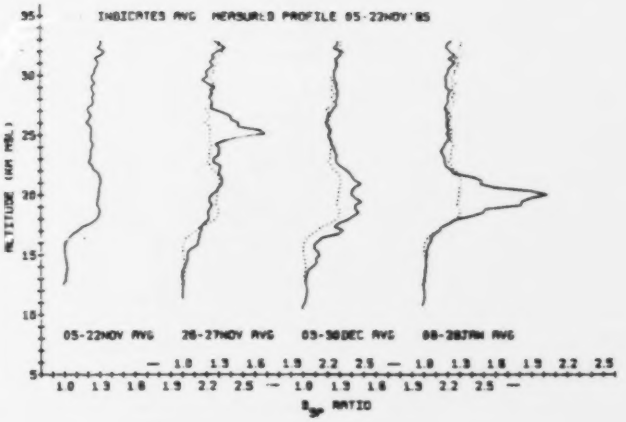

Figure 11: Average lidar profiles measured during four periods at Mauna Loa, Hawaii, courtesy of Thomas DeFoor. The dotted line superimposed on each profile represents the average 5-22 November data, just before the arrival of fresh aerosol layers.

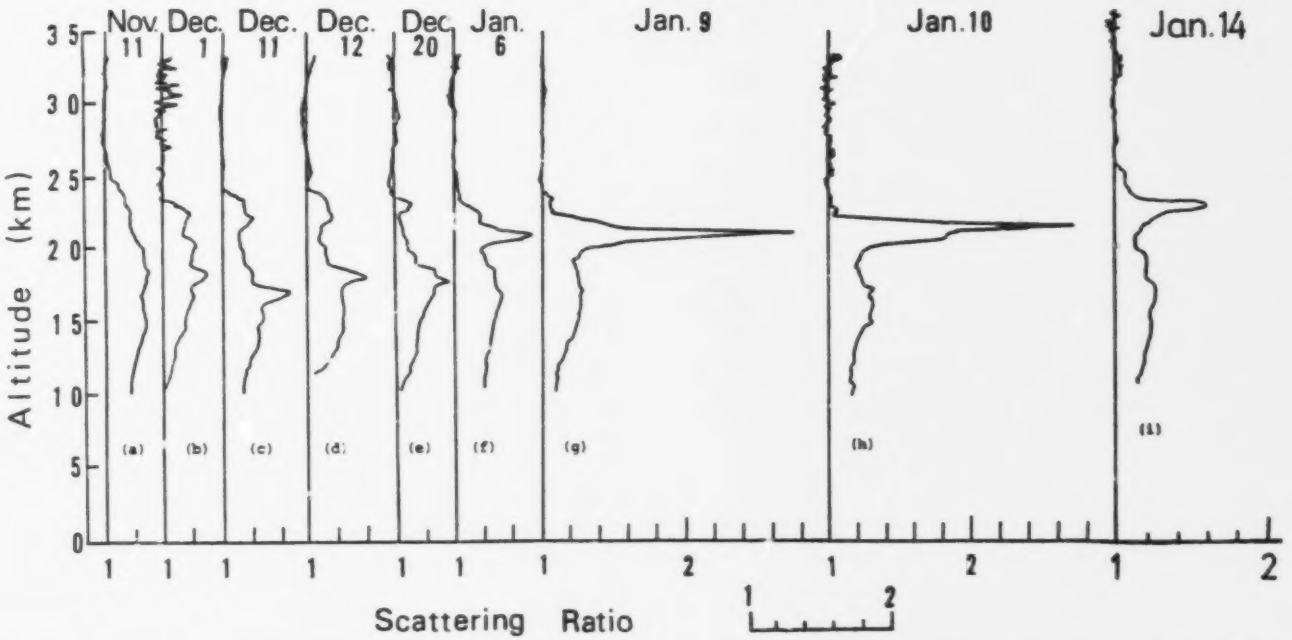

Figure 12: Lidar profiles from Tsukuba, Japan (36.2°N, 140.1°E), courtesy of Sachiko Hayashida. Solid vertical lines represent a scattering ratio of 1. Lidar wavelength is 0.53 microns.

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Atmospheric Effects (continued)

LOCATION	DATE	LAYER ALTITUDE IN KM (peak in parentheses)		BACKSCATTERING COEFFICIENT	RATIO	INTEGRATED
NASA airborne mission						
42.40°N, 61.58°W	8 Jan.	10-19	(16.6)		1.3	
67.5°N, 74.58°W	10 Jan.	10-20	(14.6)		1.4	
76.5°N, 61.17°W	14 Jan.	9-18	(13.8)		1.3	
76.63°N, 64.42°W	16 Jan.	9-22				
		19-21.5	(21.0)		2.0	
77°N, 75.77°W	16 Jan.	9-23				
		19-21.5	(20.3)		2.2	
76.78°N, 108°W	16 Jan.	9-23				
		19-21.5	(20.2)		2.1	
76.15°N, 110°W	16 Jan.	9-21	(19.0)		1.3	
68.10°N, 23.17°W	18 Jan.	10-20	(16.6)		1.2	
60°N, 47.83°W	21 Jan.	12-21				
		18-21	(19.1)		1.5	
50.63°N, 63.55°W	22 Jan.	12-21				
		17-20	(18.3)		1.6	
SAGE II satellite						
20.9°N, 56.5°E	4 Dec.	18-22	(20.5)		10 x background	
1.3°N, 179°E	6 Dec.	22-24.5	(24.0)		>10 x background	
Mauna Loa, Hawaii	8 Jan.	16-30	(18.3)	0.23×10^{-7}	1.4	0.12×10^{-3}
(19.5°N, 155.6°W)			(20.4)	0.20×10^{-7}	1.5	
	14 Jan.	16-22	(20.4)	0.57×10^{-7}	2.4	0.16×10^{-3}
	21 Jan.	17-22	(19.2)	0.47×10^{-7}	2.0	0.15×10^{-3}
			(20.1)	0.44×10^{-7}	2.1	
	28 Jan.	17-22	(19.8)	0.57×10^{-7}	2.3	0.19×10^{-3}
			(20.1)	0.55×10^{-7}	2.3	
Garmisch-Partenkirchen,	4 Nov.	10-30	(16.2)		1.4	
Germany (11°N, 47°W)	15 Nov.	9-29	(18.0)		1.4	
	1 Dec.	12-28	(17.4)		1.3	
	13 Dec.	12-27	(18.0)		1.3	
	23 Dec.	11-27	(16.2)		1.4	
	4 Jan.	12-29	(16.8)		1.3	
	21 Jan.	12-28				
		16-19	(18.6)		1.9	
		20-22.5	(21.0)		2.4	
	22 Jan.	10-29				
		?-19	(18.0)		1.8	
	26 Jan.	12-26				
		15-18.5	(17.4)		1.7	

Table 7: Lidar data from various locations, showing altitudes of aerosol layers. Note that some layers have multiple peaks. Backscattering ratios from Fukuoka, Japan are for the Nd-YAG wavelength of 1.06 microns; from Tsukuba, Japan for the Nd-YAG wavelength of 0.53 microns; all others are for the ruby wavelength of 0.69 microns. An explanation of the relationship of ruby and Nd-YAG values is on p. 15-16 of SEAN Bulletin v. 9, no. 10. Altitudes of maximum backscattering ratios and coefficients are shown for each layer at Mauna Loa; maxima were at the same altitude on 14 January. Integrated values show total backscatter, expressed in steradians^{-1}, integrated over 300-m intervals from 16-33 km at Mauna Loa and from the tropopause to 30 km at Hampton.

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Atmospheric Effects (continued)

The following is from Richard Keen.

"Enhanced twilights continued to be observed in 1985, but in general the brightness, color intensity, and duration of the twilight phenomena were not as great as in 1984. Salmon or lavender-colored twilights, with peak color intensity at a solar depression angle (SDA) of 4°, were observed on 6 February, 5 and 24 July, 1, 2, 26, 27, & 29 October, and 13 December. The concentration of observations in October may be due to the normal absence of high cirrus clouds over the W United States during the early fall. Horizontal striations were noted in the twilights of 6 February and 13 December.

"A spectacular twilight was seen on 31 December. The bright salmon color peaked at an SDA of 5°, implying a somewhat higher aerosol layer than that responsible for the twilight phenomena earlier in the year. In addition, there were pronounced horizontal striations and banding in the twilight glow. This twilight was similar to those observed in late 1982 and 1983. Enhanced twilights in early January 1986 (on the 7th and 12th) were modest 4° SDA twilights of the type observed earlier in 1985, so the bright 31 December twilight was apparently due to a passing localized aerosol cloud.

"Hemispherically averaged volcanic aerosol optical thicknesses can be derived from observations of the brightness of the moon during total lunar eclipses (Keen, 1983, Science, v. 222, p. 1011-1013). The 2 lunar eclipses of 1985 (4 May and 28 October) were observable only from the Eastern Hemisphere. Using observations from England, Spain, Austria, South Africa, and Australia for the 1985 eclipses, the following aerosol optical thicknesses have been derived:

Date	Hemisphere	Optical Depth
30 December, 1982	N	0.12
25 June, 1983 (partial eclipse)	S	0.03
5 May, 1985	N	0.04
28 October, 1985	S	0.00

The uncertainty of the derived optical thicknesses is $\pm$ 0.02. These observations indicate that the Northern Hemisphere volcanic aerosols from El Chichón decayed to 1/3 of their peak values between 1982 and 1985; the calculated e-folding decay time is 2.1 years. The Southern Hemisphere aerosol layer, which in 1983 was apparently only 1/4 as thick as the Northern Hemisphere layer, had decayed to undetectability by 1985."

Edward Brooks observed unusual sunrises and sunsets from Trinidad, Florida, and Massachusetts. On 31 December, the sunset was a vivid pink to dark purple at Key West, Florida (24.57°N, 81.60°W). At Port of Spain, Trinidad (10.63°N, 61.52°W), the 12 January evening sky was a brilliant orange to red with a dark blue crepuscular ray for about 30 minutes after sunset (solar depression angle about 15°). On 20 January, the sunset was brightly colored at Jacksonville, Florida (30.33°N, 81.67°W). Two days later at Boca Raton, Florida (26.37°N, 80.08°W), sunrise was strongly pink and sunset was also a brilliant pink with multiple dark and light crepuscular rays. Pink crepuscular rays were associated with the 5 February sunset at Newton, Massachusetts (42.33°N, 71.22°W), and the sky remained bright red for about 30 minutes after sunset (solar depression angle about 10°; note differing SDA rates at low and mid-latitudes).

Information Contacts: William Fuller, NASA Langley Research Center, Hampton, Virginia 23665 USA; Sachiko Hayashida, National Institute for Environmental Studies, Yatabe-machi, Tsukuba, Ibaraki 305, Japan; Thomas DeFoor, Mauna Loa Observatory, P.O. Box 275, Hilo, Hawaii 96720 USA; D. J. Hofmann and J. M. Rosen, Department of Physics and Astronomy, University of Wyoming, Laramie, Wyoming 82071 USA; H. Jäger,

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Atmospheric Effects (continued)

Fraunhofer-Institut für Atmosphärische Umweltforschung, Kreuzeckbahnstrasse 19, D-8100 Garmisch-Partenkirchen, West Germany; Richard Keen, CIRES, Campus Box 449, University of Colorado, Boulder, Colorado 80309 USA; Edward M. Brooks, Department of Geology and Geophysics, Boston College, Chestnut Hill, Massachusetts 02167 USA.

EARTHQUAKES

DATE	TIME (GMT)	MAGNITUDE	LAT.	LONG.	DEPTH OF FOCUS	REGION
11 January	1942	$5.3m_b$	9.59°S	77.47°W	shallow	Central Peru
15 January	2017	$6.5M_S$	21.45°S	70.40°E	shallow	Loyalty Islands
31 January	1647	$5.0m_b$	41.64°N	51.10°W	10 km	NE Ohio, USA

The 11 January earthquake struck the mountain region of Ancash, 400 km NE of Lima, where 20 houses were destroyed and 60 damaged, leaving 100 persons homeless. One person was killed and approximately 40 animals were crushed by landslides.

There were no reports of damage or casualties due to the 15 January earthquake.

The 31 January earthquake was felt in 11 states from Wisconsin to Maryland, the District of Columbia, and parts of Ontario, Canada. There was damage in the epicentral area and 13 persons were injured.

Information Contacts: National Earthquake Information Service, U. S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225 USA, Agence France Presse.

METEORITE FALL

German Democratic Republic

A 43-g stony meteorite was found (Figure 13) in a wooded area in Hohenlangenback, S of Salzwedel (about 52.8°N, 11.2°E). It was heard falling through the trees about 1.5 minutes after a fireball passed on 14 November at 1917 GMT. The average density of the object is 3.9 g/cm³. This is the first observed meteorite fall in the German Democratic Republic (DDR) in 89 years.

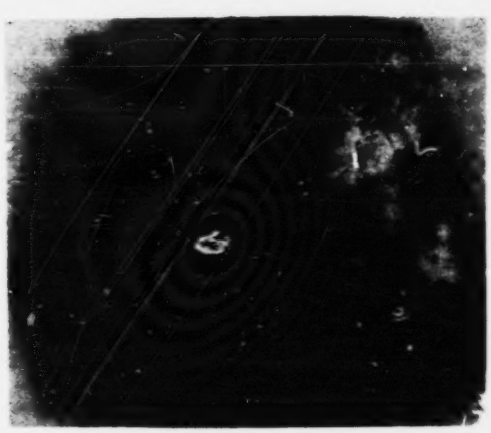

Figure 13: Photograph of meteorite found near Salzwedel, German Democratic Republic, courtesy of Jürgen Rendtel. The meteorite's diameter is approximately 2.5-3.0 cm.

Meteorite Fall (continued)

All-sky cameras were not operating because of cloudy weather conditions, but the fireball was seen by many observers in western DDR. At the beginning the meteor had a magnitude of -2 /-4. After a few seconds its brightness increased rapidly to -8/-10. At least 2 more flares followed; maximum brightness may have been -12/-14. The height at the end of the visible path was 20 km.

Information Contact: Jürgen Rendtel, Arbeitskresis Meteore, Neuer Garten 6, DDR-1500 Potsdam, German Democratic Republic.

FIREBALLS

N Germany, 6 January, 1900 GMT.
Observer: Captain Lambach and First Officer Marszalek, Lufthansa flight 949 (Hamburg-Stuttgart)
Location: S of Hannover, aircraft course 180° magnetic, altitude 10.6 km
First sighting: Azimuth 100° magnetic
Last sighting: Azimuth 160° magnetic
Duration: 5 seconds
Magnitude: Dazzling
Tail: White

Information Contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

N Luxembourg, 13 October. The following is from Hans Betlem.

"A slow-moving fireball of -8 visual magnitude was photographed by 5 Dutch stations of the European network. The fireball entered the atmosphere over northern Luxembourg and traveled a 62-km luminous trajectory in 2.5 seconds. The following results are based on 4 photographic records measured by Mark de Lignie and Hans Betlem."

	Beginning	Maximum Light	Terminal
Velocity (km/s)	26.49		(25.)
Height (km)	81.9	46.5	43.3
Latitude	50.384°N		50.739°N
Longitude	6.151°E		6.540°E
Z R	51.75°		

Radiant (2000.0)	Observed	Geocentric	Heliocentric
Alpha	28.35°±.25	29.15°±.27	-
Delta	4.20°±.13	1.6°±.22	-
Lambda			331.59°±.17
Beta			-6.40°±.11
Initial velocity (km/s)	26.49±.8	23.84±.9	35.96±.5

Orbit (2000.0)

a	1.83 A.U.
a^{-1}	.547±.042 A.U.$^{-1}$
e	.743±.025
Q	.468±.011 A.U.
ω	104.15°±.49
Ω	19.872°±0.
i	8.54°±.23

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Luxembourg (continued)

Information Contact: Hans Betlem, Dutch Meteor Society, Morssingel 35a 2312 AZ, Leiden, Netherlands.

N Iraq, 31 January, 1623 GMT.
Observer: Captain G. Scherer and First Engineer N. Langenegger, Swissair flight SR 388 (Zurich-Dhahran)
Location: 36.33°N, 39..97°E, aircraft course 100° magnetic, altitude 11.2 km
First sighting: Azimuth 130° magnetic, altitude 25°
Last sighting: Azimuth 140° magnetic, altitude 10°
Duration: 2 seconds
Magnitude: Dazzling in the first second, then decreased to brightness between the full moon and Venus
Color: White-yellow

Information Contact: Same as for Germany.

S Yugoslavia, 28 January, 0046 GMT
Observers: Captain Jericho and First Officer Nesselhauf, Lufthansa flight LH 4625 (Frankfurt-Jeddah)
Location: 42.87°N, 20.34°E, aircraft course 130° magnetic, altitude 10 km
First sighting: Azimuth 220°, altitude 15°
Last sighting: Azimuth 220°, altitude 5°
Duration: 3 seconds
Magnitude: Cockpit was brightly illuminated
Train: Persisted 1 second

Information Contact: Same as for Germany.

California, USA, 7 January, 0500 GMT (6 January, 2100 Pacific Standard Time).
Observer: Sharon Greenway
Location: Glendora, Los Angeles County (34.0°N, 118.1°W)
First sighting: Azimuth 270°, altitude 55°
Last sighting: Azimuth 255°, altitude 15°
Duration: 6 seconds
Apparent velocity: Fast
Magnitude: Brighter than the full moon
Color: White
Trail: Luminous, green
Termination: Vanished above horizon
Sounds: None heard

Information Contact: Susie Gurton, Griffith Observatory, 2800 East Observatory Road, Los Angeles, California 90027 USA.

North Carolina, USA, 24 January, 0300-0305 GMT (23 January, 2220-2205 Eastern Standard Time).
Observer: James R. Yankaskas, pilot
Location: 35.92°N, 79.25°W, altitude 1.8 km
First sighting: 285° magnetic, altitude 30°
Last sighting: 225° magnetic, altitude slightly less than 30°
Path: nearly horizontal, with a slight downward component
Duration: 3-4 seconds
Magnitude: Brighter than the full moon
Apparent size: 1/10 to 1/5 the diameter of the full moon

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North Carolina (continued)

Train: Yellowish-red, persisted 1-2 seconds after fireball disappeared
Termination: Disappeared above the horizon after fragmenting into 2 parts
Sounds: None heard
Comment: Fireball increased in size and intensity, splitting into 2 fragments of different sizes that travelled close together

Information Contact: James R. Yankaskas, 107 Deerfield Trail, Chapel Hill, North Carolina 27514 USA.

W Oregon, 31 December, 0311 GMT (30 December, 1911 Pacific Standard Time).
Observer: Channing Wilson
Location: Deschutes County, 44.31°N, 121.90°W
First sighting: Azimuth 15°, altitude 50°
Last sighting: Azimuth 340°, altitude 40°
Path: E to W; angle of descent 15°
Duration: 4 seconds
Magnitude: Brighter than the full moon; did not cast shadows
Apparent size: 1/4 the diameter of the full moon
Color: White
Tail: Short; white
Termination: No fragmentation observed
Sounds: None heard

Information Contact: Richard N. Pugh, 4617 N.E. 26th Avenue, Portland, Oregon 97211 USA.

W Oregon, 2 January, 0330 GMT (1 January, 1930 Pacific Standard Time).
Observer: Whitney Gearin
Location: Wasco County, 45.50°N, 121.30°W
Path: Seen in western sky descending at a 15° angle from altitude 80° to 40°
Duration: 3 seconds
Magnitude: Bright as the full moon
Apparent size: 1/6 the diameter of the full moon
Color: White
Tail: White; extended full length of path
Termination: Vanished above horizon without fragmenting
Sounds: None heard

Information Contact: Same as for 31 December fireball.

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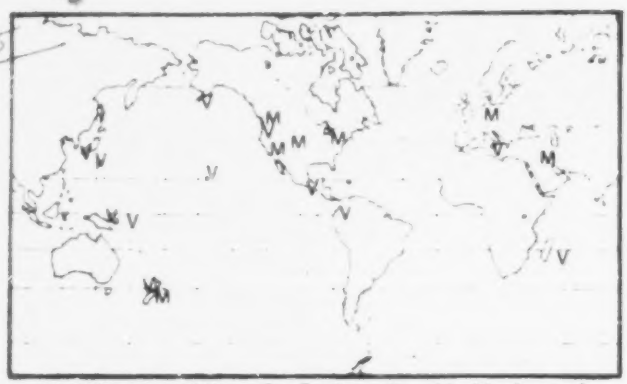

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SEAN

Scientific Event Alert Network

BULLETIN

VOLUME 11, NO. 2, FEBRUARY 28, 1986

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FIREBALLS

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Lindsay McClelland, Elizabeth Nielsen, Emily Wegert, Toni Duggan, Marjorie Summers

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(Data are preliminary and subject to change - contact the original source or SEAN before using)

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VOLCANIC EVENTS

Ruiz Volcano, Colombia (4.88°N, 75.37°W). All times are local (= GMT - 5 hours).

Colombian geologists reported that microseismic activity diminished between mid-February and mid-March, with an average of 5 high-frequency and 12-15 low-frequency events daily. Seismic events of mixed frequency also diminished, to 1 per day. Activity on 28 February was abnormally low, with only 1 low-frequency event. Epicenters were within 3-4 km of the crater, and focal depths were at 1-3 km below a datum at 4.7 km above sea level (summit elevation is 5389 m).

The vapor column reached heights of 100-800 m, without significant ash emission. Rates of SO_2 emission measured by COSPEC in early March were generally of the order of 500 metric tons per day; during the afternoon of 4 March, values of about 1000 tons per day were recorded. Rates of about 1000 tons per day had been measured a month earlier. Fissures in pyroclastic material on glaciers on the NE part of the volcano showed displacements of 20-30 mm per day. Electronic tilt instruments recorded about 0.1 microradian of inflation per day on the W flank. No significant changes were detected on the E flank.

Additional seismic information comes from Jim Zollweg. "After the 13 November eruption, a 6-station telemetry network was installed around the volcano. All stations use vertical 1 Hz seismometers and radio-telemeter to the Comité de Estudios Vulcanológicos headquarters in Manizales. Sites were chosen 4-10 km from Arenas, Ruiz's active crater. The first station was operating on 17 November, four stations were functioning by 28 November, and all six by 2 December, although some locations were changed later. Recording is analog using pen-and-ink or smoked paper.

"Seismic activity was moderate in November and December, consisting chiefly of high-frequency earthquakes with magnitudes to 3.5. There were about half as many low-frequency as high-frequency earthquakes during those months. About 1300 earthquakes were counted in December (countable events had coda lengths of at least 5 seconds on the Olleta telemetry station). In January, activity was considerably lower because of a major decrease in the rate of occurrence of high-frequency events. Only a few surface-type events (gas emission signals or avalanches) were recorded by telemetry stations in any month. Instances of harmonic tremor sustained for more than a minute were also uncommon, particularly in December. The most important tremor recorded since the stations were installed occurred 3-5 January, preceding and during a minor eruption 4-5 January (see SEAN Bulletin v. 10, no. 12). This tremor was unusual because of its wide range of frequency content; frequencies of 7 Hz or more were recorded within a few hours of its onset, and frequencies as low as 0.7 Hz occurred later in the episode.

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Ruiz Volcano (continued)

"Very few low-frequency earthquakes have been locatable, and those with epicenters that could be computed usually occurred near Crater Arenas (within the limits of accuracy of the solutions). More than 150 high-frequency earthquakes have been located, and 81 of the better solutions are plotted in figure 1. Events were located using the program HYPOINVERSE, and an ad hoc crustal model based on geological considerations. Events plotted within the network have epicentral 95% confidence limits of 1 km or less. Those plotted outside the network may have epicentral 95% confidence limits as poor as 3 km, depending on distance from the network. Focal depths of the high-frequency events are usually between 2 and 5 km (beneath a datum at 4.7 km above sea level), but depend on the crustal model used. The probable error range makes it difficult to say whether there are significant depth differences between events.

"Most of the high-frequency earthquakes occurred in one of two linear zones that intersect under the center of Ruiz. The E-W-striking zone is about 6 km long and was responsible for most of the seismicity. There is an interesting temporal pattern to the epicenters. Locations between 28 November and 5 December mainly fell in the central and eastern parts of the E-W zone, whereas vigorous swarms 6-13 December were mainly confined to the W half of the zone. There was a pronounced hiatus in high-frequency activity 14-21 December, followed by a swarm of events 22-25 December along the second zone, striking NW-SE. Between 26 December and 3 January, earthquakes reverted to a small area near the intersection of the two zones. High-frequency activity was comparatively low in the weeks following the 4-5 January eruption. First motions have been mostly compressions for nearly all events under Ruiz, suggesting a normal faulting environment. The data for the high-frequency sequences suggest the intrusion of dike-like bodies of magma along pre-existing fault zones."

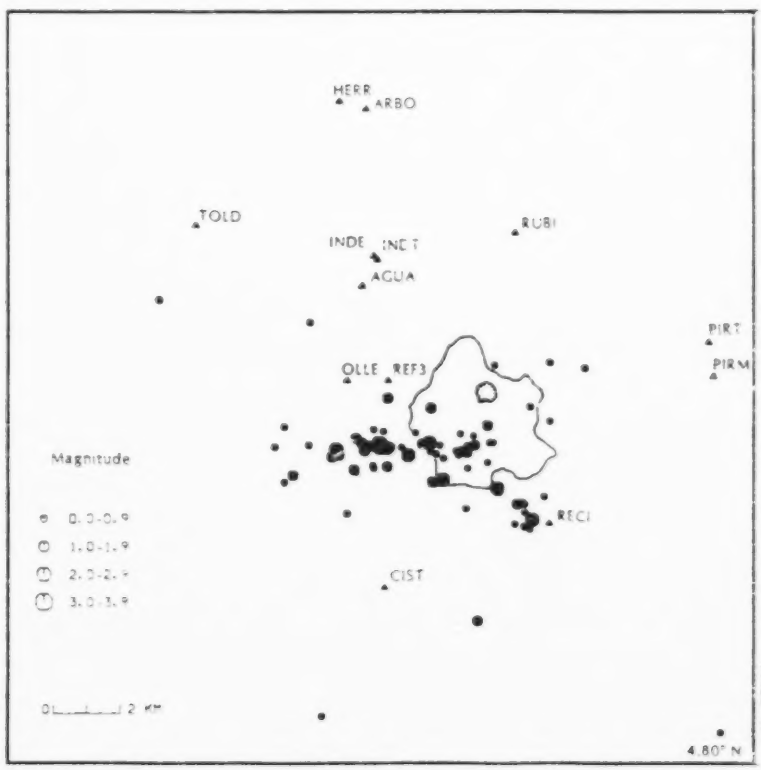

Figure 1: Epicenters 28 November 1985-21 January 1986, courtesy of Jim Zollweg. The 5000 m contour is outlined. Filled triangles are telemetered stations; others are shown by open triangles. Not all were operating simultaneously; PIRT and ARBO are no longer operating.

Ruiz Volcano (continued)

Deformation monitoring has been summarized by Barry Voight. "Preliminary data from Electronic Distance Measurement (EDM) reflector stations suggest that much of the observed summit surface deformation is due to ice movement decoupled from underlying bedrock. The data place constraints on the volume of rock susceptible to massive gravitational failure.

"EDM reflector stations (Martica and Finger) were installed at approximately 5100 m elevation near the center of the Río Azufrado headwall. They were first measured on 14 February. Preliminary data from repeated distance measurements to 7 March suggest that the motions of glacier ice and underlying bedrock are decoupled. The fracture pattern observed on the surface of the summit plateau E of the Arenas Crater dominantly reflects the propagation of crevasse patterns through the veneer of surficial deposits. And the steady outward motion of the summit area as deduced from observation of surficial fracturing and EDM monitoring mainly reflect movements in glacier ice rather than motion of underlying bedrock. At other locations, some cracks give the appearance of possibly extending into bedrock, for example at the septum separating the crater from the headwall of the Río Azufrado. Although my current impression is that all of the headwall is probably stable with respect to deep-seated rock failure, the potential for mass movement involving a portion of the crater remains to be thoroughly evaluated."

Fabian Hoyos P. reported that isotopic analyses of several hot springs and the crater fumarole were sampled on 8 July 1985 in cooperation with the Central Hidroeléctrica de Caldas (CHEC). Isotopic compositions of 8 July 1985 hot spring samples were similar to those reported in 1968 and 1980 to CHEC. Water vapor collected the same day from the summit crater fumarole had an isotopic composition corresponding to that of meteoric water precipitated at about 2800 m above sea level (table 1). Other samples collected until just before the 13 November eruption are being analyzed.

Source	$\delta^{18}O$	δD
Aguas Blancas Hot Spring	-102.1	-14.4
Termales Ruiz Hot Spring	-104.8	-13.6
Crater fumarole	-89.0	-12.9

Table 1: Isotope analyses by Sara Kealy, Arizona State University, of samples collected 8 July 1985. Data courtesy of Fabian Hoyos P. and Sara Kealy.

Information Contacts: Isabel Mejía and Eduardo Parra, Comité de Estudios Vulcanológicos, 11° Piso, Edificio Londoño, Manizales, Colombia; Adela Londoño, Luís Rodriguez, and Nelson Rojas, Universidad Nacional, Seccional Manizales, Apartado Aéreo 127, Manizales, Colombia; Nestor García, Industria Licorera de Caldas, Apartado Aéreo 82, Manizales, Colombia; Fabian Hoyos P., Estudios Geológicos, Escuela de Ciencias, Universidad Nacional, Medellín, Colombia; Jim Zollweg, U.S. Geological Survey, Geophysics Program, University of Washington, Seattle, WA 98195 USA; Barry Voight, Department of Geosciences, Penn State University, University Park, PA 16802 USA; Stanley N. Williams, Department of Geology, Louisiana State University, Baton Rouge, LA 70803 USA.

Tacaná Volcano, México/Guatemala border (15.13°N, 92.10°W). All times are local (= GMT - 6 hours).

The series of shallow earthquakes near Tacaná that began in mid-December (see last month's Bulletin) was continuing in early March. Many of the shocks were felt near the volcano. There were no apparent changes to fumaroles on and around the

Tacaná Volcano (continued)

volcano. To supplement permanent seismometers 30 km SW and 80 km N of the volcano (near Tapachula and Comitán), Mexican geophysicists installed portable instruments about 27 km NW of the volcano (at Motozintla), W of the volcano (at El Aguila) and about 6 km S of the summit (at Unión Juarez).

The majority of felt events were subduction zone earthquakes centered under the coast of northernmost Guatemala. Other events originated in a fault system NE of the volcano, in Guatemala. A third type consisted of events under the volcano, characterized by sharp P arrivals and very long S wave trains, that were strong enough to be felt and heard within 10 km of the volcano. Apparent volcanic tremor episodes with amplitudes just above noise levels were recorded 2-3 times a day. The rate of seismic energy release increased substantially 18-25 February, declined significantly after 25 February, then started to increase again on 3 March. On 3 March between 0400 and 1200, a bubble tiltmeter 6 km S of the summit (at 1800 m elevation) indicated a sharp deformation event corresponding to about 100 microradians of deflation on an azimuth of 073°. However, releveling of a line extending 1 km N and 4 km S of the tiltmeter (including one station only a few tens of meters away) revealed no changes. On 10 March about 0200, seismic instruments detected several events that looked like explosion shocks, followed by about 2 minutes of very minor tremor. The events were felt and heard by many residents of towns around the volcano, but no eruption occurred. The government of the state of Chiapas, México has prepared a contingency plan to respond to several levels of volcanic risk, including evacuation of people within 15 km of the volcano if necessary.

Information Contact: Servando de la Cruz-Reyna, Instituto de Geofísica, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México D.F., México.

Augustine Volcano, southwest Alaska, USA (59.37°N, 153.42°W). All times are local (= GMT - 9 hours).

Juergen Kienle reports that seismicity at Augustine began to increase last summer for the first time since 1976, when the volcano last erupted. Between 12 July and 7 August, approximately 300 shallow microearthquakes were recorded each day on Augustine's network of 4 seismic stations. From then until late February, a daily average of 12 earthquakes was recorded, plus occasional short bursts of seismicity. A small swarm took place during September with 100 events a day over a 2-3-day period. An intense peak occurred on 22 February between 0700 and 0800, when 70 microearthquakes were recorded on the seismometer less than 1 km from the dome, 2 hours before USGS scientists flew over the volcano and reported active degassing (see below). Since the end of February seismicity has intensified, with concentrated swarms (3-4 events/hour lasting 1 to 2 hours) occurring approximately twice a day. These microearthquakes are all shallow and indicate fracturing and degassing of the dome.

The following is a report from Betsy Yount. "On 17 February, James Riehle saw what he believed to be an explosion plume over Augustine Volcano, while on Wolverine Peak more than 300 km from Augustine. The plume rose to an estimated altitude of more than 3 km. It was dispersed by winds within approximately 0.5 hour, with the lower portion of the plume drifting W or NW and the upper portion drifting E or SE. Seismic recorders at the USGS office in Anchorage, which monitor some of the University of Alaska Geophysical Institute seismometers, had shown an increase in small events near Augustine, beginning 13 February. On 20 and 21 February, the USGS began receiving reports from observers in Homer (110 km NE of Augustine) and from pilots flying near the volcano that it was vigorously steaming.

Augustine Volcano (continued)

"On 22 February, USGS personnel flew over the volcano and confirmed that it was actively degassing from the moat around the summit dome. The main fumarolic vent was in the moat E of the dome. During the observations (between 1000 and 1018), fumarolic activity was continuous and steady. The plume was whitish, with a few grayish wisps. The SE and W sectors of the snow-covered cone were lightly dusted with ash, believed to be comminuted portions of the 1976 dome. No sign of avalanches or falling blocks from the dome were observed. During a 28 February overflight, USGS personnel noted an increase in the amount and area of fumarolic activity compared to 22 February. Augustine may be following its traditional pattern of slowly forcing the summit dome up followed by dome destruction and pyroclastic flow activity."

On 14 March, images from the NOAA-9 polar orbiting satellite showed a plume extending about 50 km south from Augustine at 1413 and 1555. No plume had been visible on 13 March, and clouds obscured the area 15-17 March. USGS scientists also flew over the volcano on 14 March, noting that the plume rose about 1000 m above the summit and looked similar to the plume seen during their overflight on 28 February.

Information Contacts: Juergen Kienle, Geophysical Institute, University of Alaska, Fairbanks, AK 99701 USA; Betsy Yount, Thomas Miller, and James Riehle, Branch of Alaskan Geology, U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508 USA; Michael Matson, NOAA/NESDIS, World Weather Bldg., Washington, DC 20233 USA.

Mt. St. Helens Volcano, Cascade Range, S Washington, USA (46.20°N, 122.18°W).

Activity remained at background levels for the 8th consecutive month, the longest repose period since activity began in 1980. February's single successful SO_2 flight (on the 10th) measured 45 $\pm$ 10 metric tons per day. Maximum deformation rates were approximately 1 mm/day. Seismicity also remained low, with no evidence of energetic gas emission.

Information Contacts: Donald Swanson, Elliot Endo, and Steven Brantley, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, Washington 98661 USA; Chris Jonientz-Trisler, Geophysics Program, University of Washington, Seattle, Washington 98195 USA.

Kilauea Volcano, Hawaii, USA (19.42°N, 155.27°W). All times are local (= GMT-10 hours).

Eruptive activity on the middle East Rift Zone of Kilauea resumed in February with the 42nd episode since the eruption started in January 1983. After 25 days of repose, the summit began to deflate on 22 February at 1000 and 10 minutes later lava fountaining began at the Pu'u O'o vent. Low-level fountaining and pahoehoe spillovers occurred intermittently until 1515 when continuous lava production began. High-amplitude harmonic tremor started 25 minutes later.

Fountain heights increased steadily over the next 7 hours until they reached about 300 m above the vent at 2230 and were sustained at that level for several hours. Four pulses of fountain jetting 360-450 m high, each lasting several minutes, occurred between 0233 and 0416 on the 23rd. After the fourth pulse at 0416, fountaining declined quickly and lava production stopped at 0420. Strong harmonic tremor ended at 0419, but was followed by moderate-amplitude, pulsating tremor for a day. Summit deflation, totalling 14.8 microradians, ended at 0700 on the 23rd; by the end of February, the summit had reinflated by 4.3 microradians (Figure 2). Episode 42 lava flows extended about 3.5 km SE from Pu'u O'o on a broad front. A small flow advanced about 1 km to the N.

Kilauea Volcano (continued)

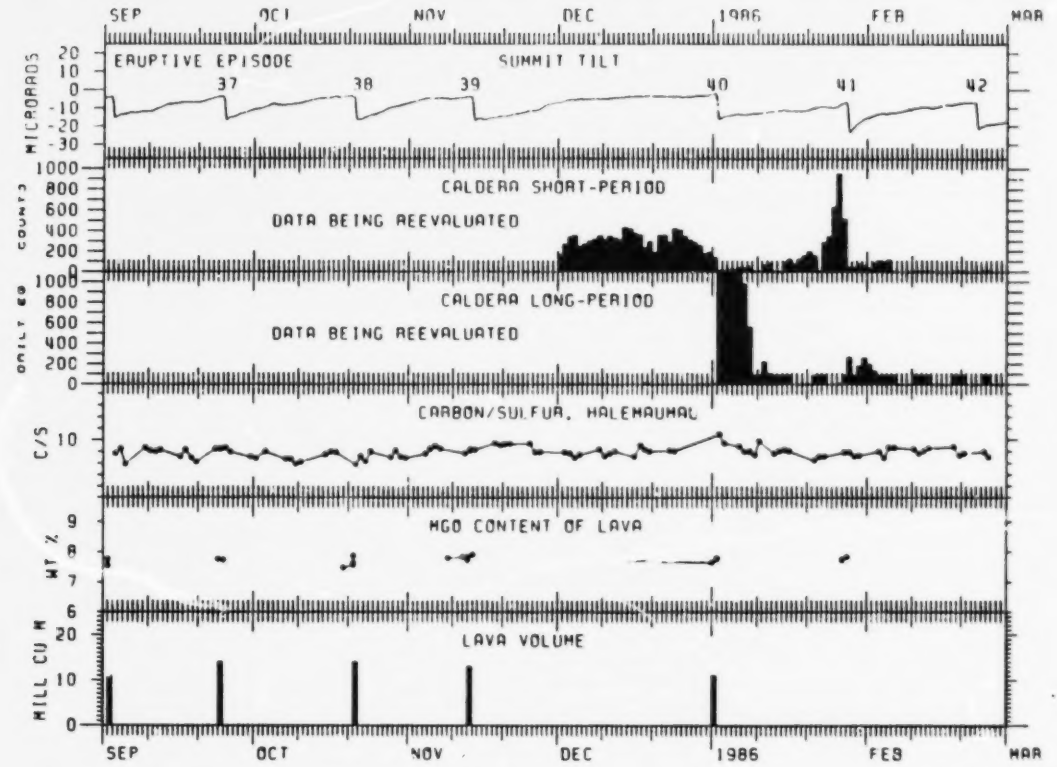

Figure 2: Six-month summary of Kilauea activity, showing summit tilt, caldera short- and long-period earthquakes, carbon/sulfur ratios of summit (Halemaumau) gases, MgO content of lava collected during and between eruptive episodes, and lava volumes. Lava volumes for episodes 41 and 42 have not yet been calculated.

Information Contacts: Christina Heliker, George Ulrich, Robert Koyanagi, and Ron Hanatani, USGS Hawaiian Volcano Observatory, P.O. Box 51, Hawaii National Park, Hawaii 96718 USA; Elizabeth Nielsen, NHB Mail Stop 119, Smithsonian Institution, Washington, DC 20560 USA.

Piton de la Fournaise Volcano, Réunion Island, Indian Ocean (21.23°S, 55.71°E). All times are local (= GMT + 4 hours).

The eruptive episode that began 29 December (see last two SEAN Bulletins) ended on 7 February. Aphyric basalt lavas covered 95% of the floor of Dolomieu crater. The volume of lava emitted is estimated to be 7 x 10^6 m^3. Deflation was observed on the summit levelling stations in mid-February. A short seismic crisis occurred on 11-12 February; events were located E of the summit at 3 km depth. Since then seismic activity has returned to a very low level. A summary of volcanic activity in 1985 is given below. The total amount of lava emitted is estimated to be 33 x 10^6 m^3.

Start of episode	14 June	5 Aug.	6 Sep.	2 Dec.	29 Dec.
Duration	24 hours	4 weeks	6 weeks	28 hours	6 weeks
Lava Volume (10^6 m^3)	1	7	17	$\leq$ 1	7

Piton de la Fournaise Volcano (continued)

Information Contacts: Hughes DeLorme and Jean-François DeLarue, Observatoire Volcanologique du Piton de la Fournaise, 14 R.N. 3, 27ème km, 97418 La Plaine des Cafres, Réunion Island; P. Bachelery, Laboratoire de Géologie, Université de la Réunion, Réunion Island.

Etna Volcano, Sicily, Italy (37.73°N, 15.00°E).

While spending the night of 5 March at the foot of the NE Crater, geologists observed ash emission every 5-15 minutes with ejection of glowing red bombs 6-7 times per hour. Bombs reached the base of the crater. Significant degassing occurred from both of the central craters (The Chasm and Bocca Nuova). However, there were no explosions, nor was glow visible at night.

Information Contacts: François Le Guern, CNRS, CFR, 91190 Gif-Sur-Yvette, France; Compagnie Republicaine de Securité de Briançan, B. P. 79, 05106 Briançan, France.

Fukutoku-oka-no-ba Volcano, Volcano Islands, Japan (24.28°N, 141.52°E).

The island formed 20 January by the submarine eruption of Fukutoku-oka-no-ba (see last month's Bulletin) has been eroded away by wave action since volcanic activity ceased. The island's disappearance was reported by the Japanese Maritime Self-Defense Force after an hour-long helicopter flight that began 8 March at 0745. The surface of the new edifice was seen under white water, and there was no sign of a volcanic plume.

On 28 January, airplane pilots observed light brown floating pumice within a roughly rectangular NW-SE-trending zone about 200 km long x 50 km wide, extending from about 100 to 300 km SE of the volcano. The pumice was in subparallel teardrop-shaped rafts roughly 4 km wide and 10 km long, elongate perpendicular to the apparent direction of drift.

Rocks collected from Fukutoku-oka-no-ba after previous eruptions in 1904, 1914, and 1982 were trachyandesites with high alkali contents.

Information Contacts: Michael Matson, NOAA/NESDIS, World Weather Bldg., Washington DC 20233 USA; Kyodo Radio, Tokyo, Japan; United Press International.

Sakurajima Volcano, Kyushu, Japan (31.58°N, 130.67°E). All times are local (= GMT + 9 hours).

Plumes from Sakurajima were recorded on images from the NOAA 9 polar orbiting weather satellite in January (see Table 2). Most plumes extended SE of the volcano.

DATE: January	11	12	20	22	27	28
TIME	1416	1409	1424	1401	1446	1446
PLUME LENGTH (km)	150-160	40-50	25-30	160	180	180

Information Contact: Will Gould, NOAA/NESDIS/SDSD, Room 100, World Weather Building, Washington, DC 20233 USA.

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Kavachi Volcano, Solomon Islands, SW Pacific (9.02°S, 157.95°E).

The submarine eruption of Kavachi described in SEAN Bulletin v. 10, no. 12 had been observed by residents of a nearby island in early December and was continuing in late February, but had ended by 3 March.

From Saira village, roughly 25 km from Kavachi on Vangunu Island, Oliver Jino reported that the eruption sequence began on 9 December. After the previously reported observations from aircraft and ships 30 December-7 January, the next sighting was on 20 January, when Dr. G. Baines noted 3 ejections of water and steam, 1.5-2 minutes apart, from a Solair plane flying more than 45 km from the volcano. An area that looked like a coral reef but was probably volcanic debris extended downcurrent from the vent. On 24 January, Mr. B. Papukera, another Solair passenger, observed a single similar ejection. No activity was evident from a Solair plane on 5 February. On 25 February, Solair Captain Don Lemon observed renewed activity ejecting water and steam to 100 m or more above sea level. Two days later, Lemon again flew near the volcano, observing gas bubbles over the vent and muddy-looking water drifting away from it, but no explosions. On 3 March, personnel in a powered dinghy from the research vessel Thomas Washington searched the area but found no sign of activity.

Information Contact: Deni Tuni, Geological Division, Ministry of Natural Resources, Honiara, Solomon Islands.

Papua New Guinea

The following is from Rabaul Volcano Observatory. All times are local (=GMT+10 hours).

Rabaul Caldera, New Britain Island (4.27°S, 152.20°E).

"Seismicity in the Rabaul caldera increased further in February, with 317 recorded events, compared to 48 in December and 72 in January. Ground deformation measurements, however, showed only minor uplift (up to 4 mm), with slight inflationary tilt and EDM changes in the Greet Harbour area."

Bagana Volcano, Bougainville Island, Solomon Islands (6.14°S, 155.19°E).

"A new extrusive phase from Bagana's summit crater commenced on 16 February. The extrusion was preceded by several days' increase in seismicity, including 3 periods of 'tremor', 30 minutes long (on the 5th and 6th) and an increase in the number of B-type events after the 10th. An increase in the amount of vapour released from the crater was also noted from the 7th onward.

"On the 16th, the vapour cloud became thick and coloured, while the seismicity rose suddenly to 140-175 events per day. From that night until the 21st, weak night glow from the crater was observed and extrusions of lava resulted in numerous incandescent avalanches of boulders on the NW, N, and NE flanks of the cone.

"At the end of the month the seismicity was still at a high level (more than 100 events per day), with periods of 'tremor' (on the 20th, 26th, and 28th), although the visible activity had declined.

"Similar phases of extrusive activity occurred in November 1985 and January 1986 and resulted in increased movement of the long-established blocky lava flow down the N flank of the volcano."

Langila Volcano, New Britain Island (5.53°S, 148.42°E).

"A moderate level of activity continued at Langila in February. Crater 2 occasionally released white to greyish vapour. A number of explosion shocks (0-10 daily) were recorded, some of which were heard at the Cape Gloucester observation post (9 km N of the volcano). Two periods of high background seismicity, consisting of sub-continuous, high-frequency 'tremor', occurred 6-11 and 21-25 February, possibly related to periods of high rainfall. Weak, fluctuating glow was observed on the night of the 20th."

Ulawun Volcano, New Britain Island (5.04°S, 151.34°E).

"Activity at Ulawun remained at a low, non-eruptive level throughout February. No significant visible or audible activity was reported, and the seismicity remained 100 events per day."

Information Contact: Peter Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

White Island Volcano, Bay of Plenty, New Zealand (37.52°S, 177.18°E).

Minor magmatic eruptive activity resumed at White Island about 1 February from a new vent within the 1978 Crater complex. On 3 February helicopter pilot Ian Johnson observed a new active vent and associated tephra fall.

About 15 low-frequency B-type earthquakes occurred per day from December into February with unusually large (50 mm P/P) amplitudes, although a gradual decline in amplitudes was apparent. Significant periods of volcanic tremor were recorded in January (11, 19, 20-21, 25-29) and February (1-5) but no vent-forming episode could be clearly recognized.

When geologists visited the volcano 10 February, there was a new vent about 25 m in diameter near the base of the E crater wall, farther E than any vent of the 1976-1982 eruption sequence. The vent emitted vapor at a moderate rate and a small amount of very fine ash was occasionally present in the gas plume.

A fresh layer of ash, 10-15 mm thick, was on the main crater floor to 150-200 m E of the new vent and a small ejecta apron extended 30-50 m W of the vent. Small scoria bombs were sparsely scattered on the surface within 50 m of the new vent. Bombs were rarely larger than 100 mm in diameter. One had clearly flattened on impact, indicating it was still soft when it fell. The scoria is fresh, dark brown, vesiculated glassy andesite with phenocrysts of plagioclase and pyroxene. Recently deposited tephra comprise reworked crater-fill detritus, some fresh crystals, and brown glass.

Fumarole temperatures of 350-360°C were measured on 10 February, 25° cooler than on 13 November (see SEAN Bulletin v. 10., no. 11) and 15-25° cooler than on 7 February. COSPEC measurements on 7 February showed an SO_2 emission rate of 570 metric tons per day, a substantial increase over the 320 tons per day detected on 21 November 1984 and 350 tons per day recorded on 7 January 1985.

The current magmatic activity is the first at White Island since January 1984 (see SEAN Bulletin v. 9 no. 2).

White Island Volcano (continued)

Information Contacts: New Zealand Geological Survey, P. O. Box 499, Rotorua, New Zealand; Philip Kyle, Department of Geosciences, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801 USA.

Ruapehu Volcano, North Island, New Zealand (39.28°S, 175.57°E). All times are local (= GMT + 13 hours).

Hydrothermal eruptions, apparently accompanied by felt earthquakes, were observed 8 and 9 February. On 8 February at 1202, ranger Lisle Irwin saw a vigorous steam column rise to more than 150 m above Crater Lake and heard loud roaring from his vantage point 2 km to the NE. Within Dome Shelter, about 350 m NNW of the lake, Rob McCallum felt what he described as a slight earthquake during the eruption. Irwin noted no fresh ejecta deposits around the lake after the eruption. At 1517, he observed a second apparently smaller eruption that produced a steam column and audible water surges over the lake's outlet channel. While flying over the crater the next day at 0719, ranger Paul Dale saw a small column of muddy water rising to about 5 m before it was obscured by steam. Between 1300 and 1330, two climbers saw a "high bubbling circle in the middle of the lake and at the same time felt the ground shake".

When geologists visited the crater 11 February, lake temperature had risen to 46°C (from 29°C on 14 January) and there was evidence of surging of 1 vertical meter or more within the previous 12-24 hours. Strands of sulfur were floating on the lake and there was a strong odor of SO_2. Activity was similar on 14 February, and there appeared to have been additional but somewhat weaker surging in the preceding 24 hours. Deformation surveys 11 and 14 February suggested minor deflation since a small inflation peak was measured in mid-January. The lake temperature had dropped to 34°C by 26 February and there was no evidence of further eruptions.

Information Contact: New Zealand Geological Survey, P. O. Box 499, Rotorua, New Zealand.

Atmospheric Effects

Lidar data from Mauna Loa, Hawaii (19.5°N, 155.6°W) on 5 February showed continued development of the aerosol layer centered at about 20 km (table 3 and figure 3). The entire profile was depressed on the 12th, but a week later the 20 km layer had strengthened and backscattering was slightly enhanced above 25 km. By 28 February, the higher layer had become prominent, the first significant enhancements detected at that altitude over Mauna Loa since 26-27 November (probably from Ruiz; see SEAN Bulletin v. 10, no. 11). From Hampton, Virginia (37.1°N, 76.3°W), lidar data on 14 February showed a layer centered around 20 km that was at a similar altitude but weaker than layers observed in Japan in January (see last month's Bulletin). Lidar profiles from the segments of the NASA airborne mission W of Thule, Greenland (about 77.5°N, 69.5°W) were similar to profiles from Tsukuba, Japan 9-10 January (see table 3 and last month's Bulletin).

Balloon flights over Laramie, Wyoming (41°N, 105.5°W) on 3 and 22 February detected no layers of optically active aeosols (radius > 0.15 microns) or condensation nuclei (CN, radius > 0.01 microns) that could be associated with recent volcanic activity. As reported in last month's Bulletin, an increase in CN at 25 km on 3 February was attributed to evaporation and recondensation of older aerosols, rather than a new volcanic event.

Atmospheric Effects (continued)

From Milliville, New Jersey (39.4°N, 74.9°W), Fred Schaaf observed an unusual sunrise on 11 January. Glow reached 15° altitude at 0702 and NE-SW horizontal striations were visible that seemed to be at higher altitudes than normal weather clouds. The intensity of the effects were similar to those observed after the 1980 Mt. St. Helens eruption, but much weaker than those that followed the eruption of El Chichón in 1982.

TABLE 3

LOCATION	DATE	LAYER ALTITUDE IN KM (peak in parentheses)		BACKSCATTERING COEFFICIENT	RATIO	INTEGRATED,
Mauna Loa, Hawaii (19.5°N, 155.6°W)	5 Feb.	16-22	(20.1)	0.76 x 10^{-7},	2.8	0.19 x 10^{-3}
			(20.7)	0.71 x 10^{-7},	2.9	
	12 Feb.	17-22.5	(22.7)	0.25 x 10^{-7},	1.7	0.11 x 10^{-3}
	19 Feb.	16.5-22	(20.7)	0.44 x 10^{-7},	2.2	0.13 x 10^{-3}
	28 Feb.	17-23	(20.1)	0.28 x 10^{-7},	1.7	0.13 x 10^{-3}
		25-29	(25.5)	0.11 x 10^{-7}	1.7	
Hampton, Virginia (37.1°N, 76.3°W)	14 Feb.	10-24	(15.5)		1.4	0.28 x 10^{-3}
		18-21			1.25	
	5 March	10-25	(16.4)		1.6	
NASA airborne mission						
42.40°N, 61.58°W	8 Jan.	10-19	(16.2)		1.3	0.1 x 10^{-3}
67.5°N, 74.58°W	10 Jan.	10-20	(14.6)		1.4	0.19 x 10^{-3}
77°N, 75.77°W	16 Jan.	9-23				0.17 x 10^{-3}
		19-21.5	(20.3)		2.2	
77°N, 93°W	16 Jan.	9-23				0.25 x 10^{-3}
		18.8-21.5	(19.8)		2.6	
76.15°N, 110°W	16 Jan.	9-21	(19.0)		1.3	0.19 x 10^{-3}
60°N, 47.83°W	21 Jan.	12-21				0.16 x 10^{-3}
		18-21	(19.1)		1.5	

Table 3: Lidar data from various locations, showing altitudes of aerosol layers. Note that some layers have multiple peaks. Data from the NASA airborne mission update preliminary values listed in last month's Bulletin. Airborne mission data in last month's Bulletin from 76.63°N, 64.42°W were taken at the Nd-YAG wavelength of 0.53 microns; all others are for the ruby wavelength of 0.69 microns. An explanation of the relationship of ruby and Nd-YAG values is on p. 15-16 of SEAN Bulletin v. 9, no. 10. Integrated values show total backscatter, expressed in steradians^{-1}, integrated over 300-m intervals from 16-33 km at Mauna Loa and from the tropopause to 30 km at Hampton and on the NASA airborne mission. When different, altitudes of maximum backscattering ratios and coefficients are shown for each layer at Mauna Loa.

Information contacts: Thomas DeFoor, Mauna Loa Observatory, P. O. Box 275, Hilo, Hawaii 96720 USA; William Fuller, NASA Langley Research Center, Hampton, Virginia 23665 USA; J. M. Rosen and D. J. Hofmann, Department of Physics and Astronomy, University of Wyoming, Laramie, Wyoming 82071 USA; Fred Schaaf, R. D. 2, Box 248, Millville, New Jersey 08332 USA.

Atmospheric Effects (continued)

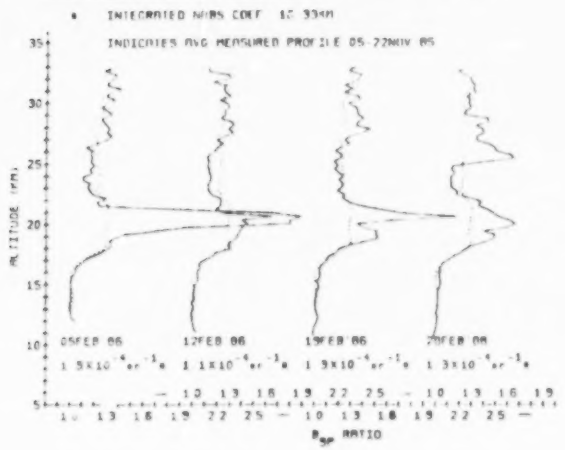

Figure 3: Lidar profiles from Mauna Loa, Hawaii (19.5°N, 155.6°W) 5-28 February, courtesy of Thomas DeFoor. The dotted line superimposed on each profile represents the average data 5-22 November, before the arrival of new aerosols over Hawaii.

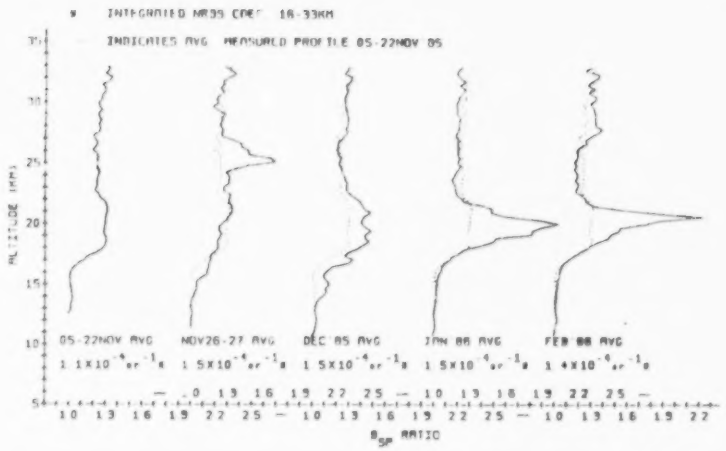

Figure 4: Average lidar profiles measured during five periods at Mauna Loa Hawaii, courtesy of Thomas DeFoor. The dotted line superimposed on each profile represents the average 5-22 November data as in figure 3.

EARTHQUAKES

No earthquakes of magnitude 6.5 or greater were recorded by the Worldwide Seismic Net in February, nor were there any shocks known to have caused casualties or substantial damage during that month.

FIREBALLS

SW Canada/NW USA, 19 February 0519 GMT (18 February 2119 Pacific Standard Time).

More than 100 people from Oregon and Washington, USA, and British Columbia, Canada, witnessed a bright fireball. Northern observers generally saw a bigger and brighter fireball than southern observers; sounds were also reported from northern locations. A summary of reports follows.

Locations: in Oregon; Keizer, Marion County (44.96°N, 123.13°W)
E Hood River, Hood River County (45.58°N, 121.42°W)
in Washington; Castle Rock, Cowlitz County (45.25°N, 122.83°W)
Grays River, Wahkiakum County (46.33°N, 123.53°W)
Path: S to N at about 45° angle of descent
Duration: 4-6 seconds
Magnitude: For northern observers the fireball was as bright as daylight but green color; as bright as or brighter than the full moon for southern observers; several reported a moving blue or green shadow
Apparent size: 1/2 to 6 times the diameter of the full moon
Color: Red, copper, yellow-blue and green seen in south; *green and blue-green* colors reported from the north
Trail: Ranged from 5-30° in length, green to northern observers and other colors to southern observers

SW Canada/NW USA (continued)

Termination: Southern observers saw it disappear below the horizon; northern observers saw it fragment or explode; several reported sparks or flames from the fireball
Sounds: Low-pitched swishing heard in Portland, Oregon as fireball passed; sonic boom heard 24 km NE of Vancouver, Washington

Information Contacts: Richard N. Pugh, 4617 N.E. 26th Avenue, Portland, Oregon 97211 USA; David Dodge, Gordon Southam Observatory, 1100 Chestnut Street, Vancouver, British Columbia, V6J 3J9, Canada.

German Democratic Republic, 14 November, 1717 GMT.

More than 200 observers reported a fireball that produced a 43-g meteorite (see last month's Bulletin). The fireball began as a -4 magnitude object seen only by a few observers. After 5 seconds it suddenly brightened to -8 magnitude. Two more flares (about -10 and -12 magnitudes) followed. The fireball then fragmented and decreased in magnitude.

Zones of different sounds were reported along the fireball's trajectory. Near the impact point, explosions and rumbling sounds were heard. At distances of 30, 50, 70, and 90 km, there were 10-km-wide zones of electrophonic hissing and rolling noises plus some whistling, rustling, humming, and roaring. Sonic booms and fracture noises were heard between these zones. No sounds were reported at about 20 km and 60 km from the impact point.

Path:

	Height (km)	Latitude	Longitude
First sighting	100 ±10	52.58 ±0.1°N	9.26 ±0.2°E
First flare	55 ±5	52.7 ±0.1°N	10.2 ±0.2°E
End of luminous path	20 ±1	52.757 ±0.025°N	11.05 ±0.05°E
Impact point	------	52.727°N	11.07°E

Mineralogical and chemical investigations on the meteorite are being performed at the Naturkundemuseum, Humboldt University, Berlin.

Information Contact: J. Rendtel, Arbeitskreis Meteore, Neuer Garten 6, Potsdam, DDR-1500, German Democratic Republic.

North Island, New Zealand, 30 November, 1985, 0858 New Zealand Daylight Time (29 November 1958 GMT).
Observer: G. E. Kingsbury
Location: N of Carterton, Wairarapa (41.0°S, 175.3°E)
Path: WNW to ESE at 20-30° angle of descent
Duration: 5 seconds
Apparent velocity: Medium
Magnitude: Bright as the full moon
Color: White
Trail: None reported
Termination: Passed out of view while still bright
Sounds: Rushing, roaring sound heard as fireball passed
Comment: Flames were seen with the fireball and small pieces fell away as it passed

Information Contact: John Morgan, West Coast Road, Renwick, Marl, New Zealand.

Saudi Arabia/Iran, 5 February, 0233 GMT.
Observers: Captain J. Grant, First Officer D. Townsend, Systems Officer K. Tym, of Quantas Airways flight 5 (Bombay to Frankfurt)
Location: 48.24°N, 45.25°E; aircraft path 290° magnetic; altitude 10.6 km
First sighting: Azimuth 320°, altitude 30°
Last sighting: Azimuth 250°, altitude 15°
Duration: 10 seconds
Magnitude: Very bright with a marked trail
Train: Luminous
Termination: Broke into fragments before disappearing

Information Contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

S California, USA, 22 January, 1030 GMT (0230 Pacific Standard Time).
Observer: Todd Wright
Location: Southern Los Angeles County (33.5°N, 118.3°W)
Path: Parallel and 10° above horizon
Duration: 10 seconds
Apparent velocity: Medium
Magnitude: Brighter than the full moon
Color: Green
Trail: Yellow, 10° long
Termination: No fragmentation
Sounds: Loud noise like train heard with passing of fireball

Information Contact: Susie Gurton, Griffith Observatory, 2800 East Observatory Road, Los Angeles, California 90027 USA.

Colorado, USA, 25 February, 0356 GMT (24 February, 2056 Mountain Standard Time).
Observer: Mark A. Heifner
Location: Denver (39.684°N, 104.988°W)
First sighting: Azimuth 120°, altitude 50°
Last sighting: Azimuth 125°, altitude 10°
Path: Began in SE portion of Leo then headed downward toward horizon
Duration: 2-3 seconds
Apparent velocity: Slow
Magnitude: -8
Color: Orange, edges silver
Trail: Luminous, silver, contained sparks, length 40°
Termination: Passed out of view behind building while still bright
Sounds: None heard

Information Contact: Mark Heifner, 37 E Colorado Ave., Denver, CO 80210 USA.

NW Oregon, USA, 6 February, 0445 GMT (5 February, 2045 Pacific Standard Time).
Observer: Tom Kreick
Location: Portland, Multnomah County (45.52°N, 122.47°W)
First sighting: Azimuth 345°, altitude 70°
Last sighting: Azimuth 345°, altitude 35°
Duration: 3 seconds
Magnitude: Bright as the full moon, fading as it travelled
Apparent size: 1/2 the diameter of the full moon
Color: White

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NW Oregon (continued)

Trail: 5° long
Termination: Vanished above the horizon; no fragmentation seen, though sparks were apparent with the fireball
Sounds: None reported

NW Oregon, USA, 6 February, 0550 GMT (5 February, 2150 Pacific Standard Time).
Observer: James Gronsand
Location: Portland, Multnomah County (45.50°N, 122.58°W)
First sighting: Azimuth 305°, altitude 40°
Last sighting: Azimuth 225°, altitude 40°
Duration: 3 seconds
Magnitude: Bright as the full moon
Apparent size: 3x the diameter of Venus
Color: Yellow-white
Trail: Blue, extended 1/3 of the path
Termination: Passed out of view behind trees while still bright; no fragmentation seen
Sounds: Hissing heard as fireball passed; no sonic booms were heard

Information Contact: Richard Pugh, 4617 NE 26th Ave., Portland, OR 97211 USA.

N Oregon, USA, 10 February, 0320 GMT (9 February, 1920 Pacific Standard Time).
Observer: David Reid
Location: Rufus, Sherman County (45.5°N, 120.6°W)
First sighting: Azimuth 90°, altitude 30°
Last sighting: Azimuth 150°, altitude 0°
Path: From Cancer to Canis Major
Duration: 15 seconds
Apparent velocity: Medium
Magnitude: Bright as the full moon
Color: Orange and white
Trail: Luminous, white, with sparks
Termination: Disappeared above horizon; no fragmentation
Sounds: None heard

Information Contact: Stephen Stout, 1602 Observatory Dr., Goldendale, WA 98620 USA.

E Pennsylvania/S New Jersey, USA, 15 February, 0830 GMT (0330 Eastern Standard Time).

Observers: Greg Youngers	Betty Ciabatoni
Location: Warminster, Bucks County, PA (40.0°N, 75.1°W)	Ocean City, Atlantic County, NJ (39.16°N, 74.35°W)
Path: S to NE	Appeared to descend into Ocean City Bay
Duration: 10 seconds	
Magnitude: Illuminated ground in snowstorm	Lit landscape
Apparent size: At least size of full moon	
Color: Whitish-yellow	Orange
Trail: Small, white center surrounded by yellow with blue margin	
Termination: Exploded into many fragments at treeline	Fragmented into 2 parts before disintegrating
Sounds: Hissing noise became louder as fireball passed; duration 5 seconds	None reported

Information Contact: Laura Hammonds Misajet, Fels Planetarium, Franklin Institute Science Museum, 20th & The Parkway, Philadelphia, PA 19103 USA.

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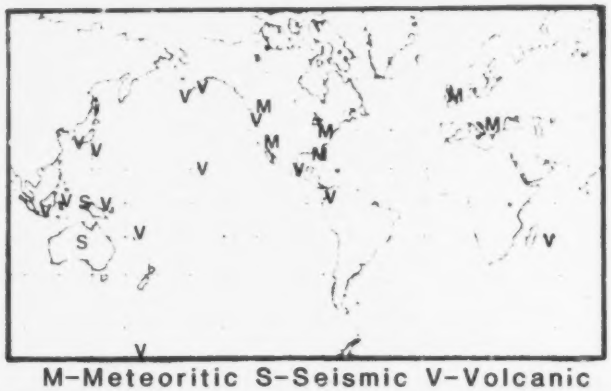

M-Meteoritic S-Seismic V-Volcanic

SEAN
Scientific Event Alert Network

BULLETIN

VOLUME 11, NO. 3, MARCH 31, 1986

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Lindsay McClelland, Elizabeth Nielsen, Emily Wegert, Toni Duggan, Marjorie Summers
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VOLCANIC EVENTS

Augustine Volcano, southwest Alaska, (59.37°N, 153.42°W). All times are local (= GMT - 9 hours).

Seismicity at Augustine began to increase during the summer of 1985 for the first time since the 1976 eruption. Emissions of plumes containing some ash were first reported in mid-February, accompanied by a further increase in seismic activity (see last month's Bulletin). A series of powerful explosions 27-31 March sent eruption clouds into the stratosphere and generated pyroclastic flows that reached the sea. Ash was deposited over a wide area and international air traffic was disrupted.

Figure 1: USGS oblique airphoto of Augustine from the S on 27 March, showing the eruption column extending to the NE & fresh pyroclastic flow/lahar deposits on the flanks.

Betsy Yount reports that "Augustine volcano began to erupt during the early morning of 27 March. Observers in fishing boats 55 km SE of the volcano and ashore in Homer, 110 km ENE, reported 'orange flashes' and 'smoke and fire' from the volcano between 0200 and 0528. A strong sulfur smell was reported from Homer to Kenai (175 km NE of Augustine). The leading edge of the main plume moved up the E side of Cook

Excerpts from the SEAN Bulletin are printed in EOS, a publication received weekly by members of the American Geophysical Union (2000 Florida Avenue, NW, Washington, DC 20009, phone 202:462-6903; marketing department, toll-free 800:424-2488). The complete Bulletin is available from AGU in the microfiche edition of EOS, as a microfiche supplement, or as a paper reprint. Single issues of the Bulletin on microfiche (from v. 6, no. 1 through the current issue) cost $1.00. For paper reprints (v. 1, no. 1 through the current issue) order SEAN Bulletin (give date and volume number) through AGU Separates: $3.50 for the first copy of each issue to those who do not have a deposit account; $2.00 to those who do; additional copies of each issue are $1.00. A complete volume of paper reprints (12 issues; 15 in volume 1) costs the annual subscription rate. AGU offers SEAN Bulletin subscriptions on a calendar-year basis at $18/year to US addresses and $28/year to all other countries. Orders must be prepaid; make checks payable to AGU. SEAN does not handle any Bulletin orders.

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Augustine Volcano (continued)

Inlet, depositing an estimated 1.5 cm of ash on Kenai and dusting the Anchorage area (260 km NE of the volcano). Numerous major eruptive events with column heights estimated at 9.1-12.2 km punctuated a continuous eruptive plume of varying ash content (figures 1 and 2). Major bursts were recorded at 1023, 1545, 1646, and 1724. During 27 March several lahars were generated on the S flank of the volcano, and pyroclastic flow activity was reported.

"Similar eruptive behavior continued through the next day, with column heights generally estimated at 6.1-7.6 km, and perhaps as high as 14.3 km at 1533. Pyroclastic flows down the N flank of Augustine accompanied these bursts. Most were of insufficient volume or speed to reach the sea. On 29 and 30 March, a continuous eruptive plume with varying ash content rose to elevations of 3-4.5 km; eruptive events with high ash columns were less frequent than on 27 March. During periods of high plume ash content, pyroclastic flows were spilling from the summit vent area at a rate of one every 4 to 10 minutes (figure 3). As before, most did not reach the sea.

"The final major eruptive ash column was recorded on 31 March at 0952 with an estimated height of 11.6-12.2 km. This burst was accompanied by large pyroclastic flows which entered the sea (on both sides of the University of Alaska Geophysical Institute's Burr Point Cabin on the N side of the island) generating billowing white plumes to 1.5 km as they reached the water. Both seismicity and ash content of the plume tapered off after 31 March.

Figure 2: LANDSAT image (number 5075620463) of Augustine on 27 March at 1146, showing a vigorous vertical eruption column and pyroclastic flow deposits. Image courtesy of John Miller, Geophysical Institute, University of Alaska.

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Augustine Volcano (continued)

Figure 3: USGS oblique airphoto of Augustine's upper N flank on 30 March, showing a pyroclastic flow advancing down the near flank. The ascending eruption column moving away to the SE casts a strong shadow to the W (right).

"Air traffic was disrupted at Anchorage International Airport, a major transportation hub, for several days because of ash clouds in the area. On 29 March, a Sabena Airlines DC-10 suffered significant abrasion of windshield and turbine parts while descending to Anchorage airport in near zero visibility conditions caused by ash in the atmosphere. Businesses and offices in Anchorage closed early on 27 March after requests from the utility company to curtail electrical usage because of potential shutdowns of turbine generators. Postal service was disrupted. An air quality health alert was in effect on 28 March due to hign particulate concentrations."

On 3 April at about noon, COSPEC measurements by William Rose from a fixed wing aircraft indicated that SO emission was occurring at a rate of about 24,000 metric tons per day, probably a significantly lower rate than during earlier more vigorous activity. Calculations based on COSPEC measurements the previous afternoon suggested

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Augustine Volcano (continued)

that roughly 70,000 metric tons of SO_2 may have been present between 1.5 and 4.5 km altitude, within a circular area (about 250 km diameter) extending between Anchorage and Augustine. SO_2 from eruptions on 27 and 31 March was detected by the TOMS instrument of the Nimbus-7 satellite. Total SO_2 content was significant, but its magnitude has not yet been determined.

Many images from the NOAA 6 and 9 polar orbiting weather satellites showed plumes, extending as much as 450 km from Augustine. NOAA scientists estimated possible plume heights by comparing radiosonde data on wind directions at various altitudes with directions of plume movement observed on satellite images (table 1). Estimates ranged to 24 km, but elevations often could not be determined uniquely because of similar wind patterns at different altitudes. Infrared imagery generally showed a hot spot over the volcano, where heat saturated the temperature sensors.

TABLE 1

Date/time	Satellite	Plume length (km)	Direction	Altitude estimate (km)
27 Mar/1516	NOAA 9	120	NE	7 or 9
27 Mar/1650	NOAA 6	180	NE	7 or 9
28 Mar/0509	NOAA 9	200-250	NE	10
28 Mar/1505	NOAA 9	30	E	21
28 Mar/1826	NOAA 6	45	E	21
29 Mar/1455	NOAA 9	5	SE	no data
30 Mar/1444	NOAA 9	450	SE	3, 5.5, or 7
30 Mar/1629	NOAA 9	150	SE	3, 5.5, or 7
30 Mar/1854	NOAA 6	80	SE	1.5 or 18.5
30 Mar/1917	NOAA 6	150	SE	3, 5.5, or 7
31 Mar/1433	NOAA 9	160	SE	1.5 or 18.5
3 Apr/1403	NOAA 9	200	SE	16 or 24
3 Apr/1542	NOAA 9	250+	SE	16 or 24
3 Apr/1921	NOAA 6	150	SE	16 or 24
5 Apr/1520	NOAA 9	150	E	3
5 Apr/1833	NOAA 6	150	E	3
6 Apr/1512	NOAA 9	100	ESE	3
6 Apr/1808	NOAA 6	100	ESE	3

After a substantial increase in the number of earthquakes on 25 March (figure 4), seismic data indicated that the eruption began at about midnight 26/27 March. On the 27th the island's 5 seismic stations recorded intense high frequency shallow seismicity. Superimposed pulses that saturated the instruments for several-minute periods were believed to be associated with eruptive bursts.

On 28 March, larger seismic events (magnitudes > 2) began to be recorded at stations 40 and 80 km from Augustine (figure 5). These occurred during periods of increased seismic intensity at island stations and were associated with reports of ash bursts. Seismicity continued with variable intensity over the next few days. Seismometers on the N side of the island sensed more activity than those on the other flanks, presumably indicating passage of pyroclastic flows down that side of the volcano.

On 31 March, a large seismic event, associated with the last major ash explosion, began at 0955 and lasted approximately 15 minutes. The signal contained 3 major pulses and had an average magnitude of 2.75. Seismicity was quiet for a day, then resumed briefly before ceasing to be recorded at seismometers 28 km away (figure d).

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Augustine Volcano (continued)

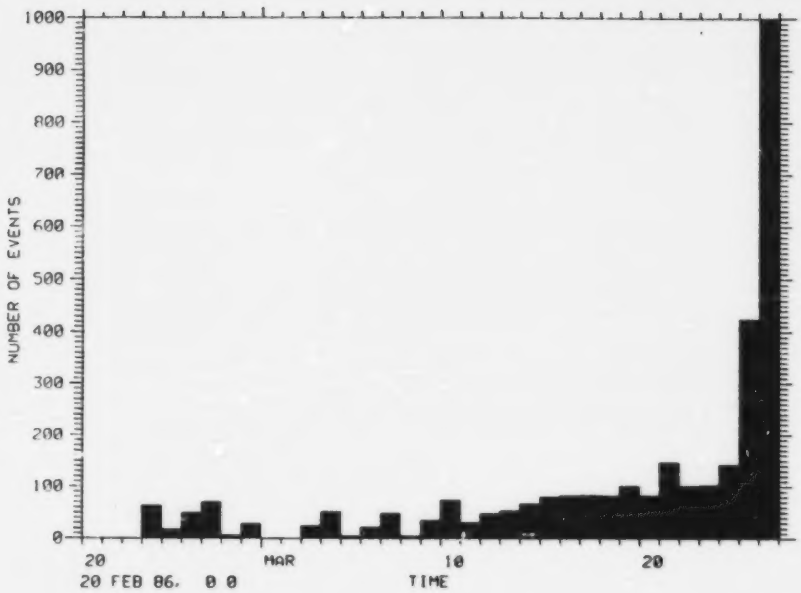

Figure 4: Number of seismic events per day at Augustine, 20 February-26 March, courtesy of John Power, University of Alaska.

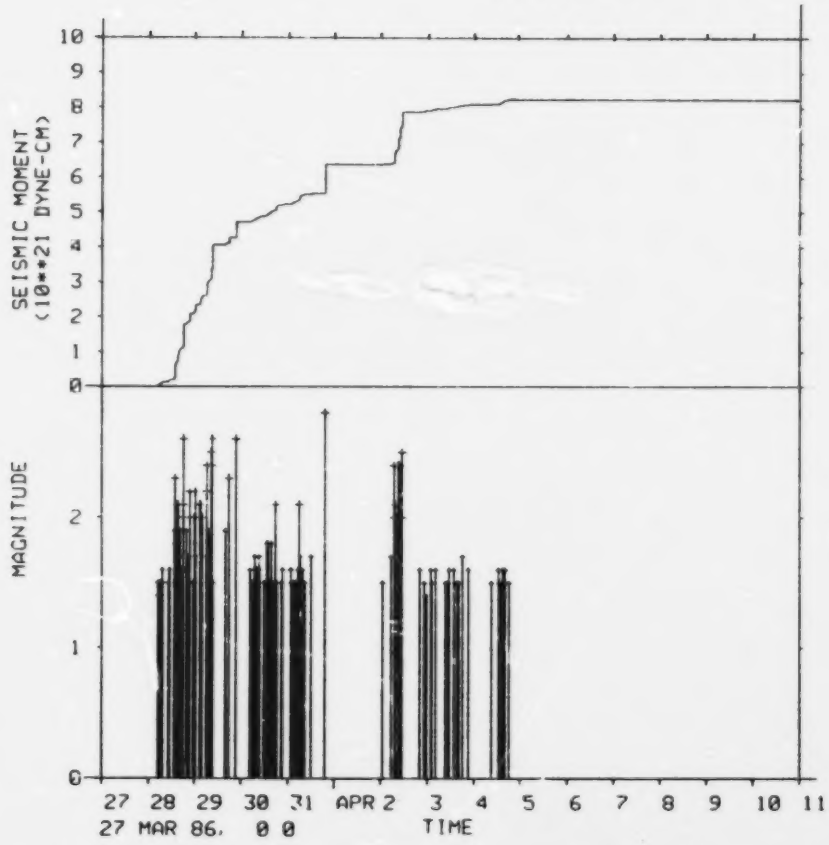

Figure 5: Cumulative seismic moment of explosion earthquakes vs time, 28 March-4 April (top); and magnitudes vs time as recorded by a University of Alaska seismic station 28 km N of the volcano, 28 March-10 April (bottom). As of 16 April, no significant events had been recorded at that station since 4 April. Times and dates are GMT. Plot courtesy of Elliot Endo.

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Augustine Volcano (continued)

During the first week of April, poor weather conditions precluded systematic observation of the volcano, but continuous seismicity indicated that a continuous plume, carrying variable amounts of ash, was being emitted from the volcano. During an overflight on 2 April, pyroclastic flows were observed advancing down the N side of the volcano. On 3 April an airplane pilot reported a plume to 3 km. During an overflight on 6 April, "boil-over" type pyroclastic flows were being emitted from the volcano. During the same day, from separate aircraft, Juergen Kienle and USGS scientists were able to make their first good observation of the summit. They both noted that most of the 1976 dome was still intact, with some loss on the S side. There were no signs of a new dome.

On 10 April, Juergen Kienle noted that: 1) A virtually continuous plume containing variable amounts of ash had been emitted from the summit since the eruption's onset. 2) No coarse (subplinian) deposits had been seen during overflights. Sampling on the island had been impossible, but fine brown ash appeared to cover the entire island. 3) Scanning electron micrographs of ash collected in Anchorage on 28 March and in Homer following the 31 March explosion show blocky textures typical of phreatomagmatic eruptions. 4) All earthquakes have been located at approximately sea level (figure 6). 5) Most of the 1976 dome is still in place. These data suggested to Kienle that only phreatic or phreatomagmatic activity had occurred, produced by dike injection to approximately sea level, where magma came into contact with the water table.

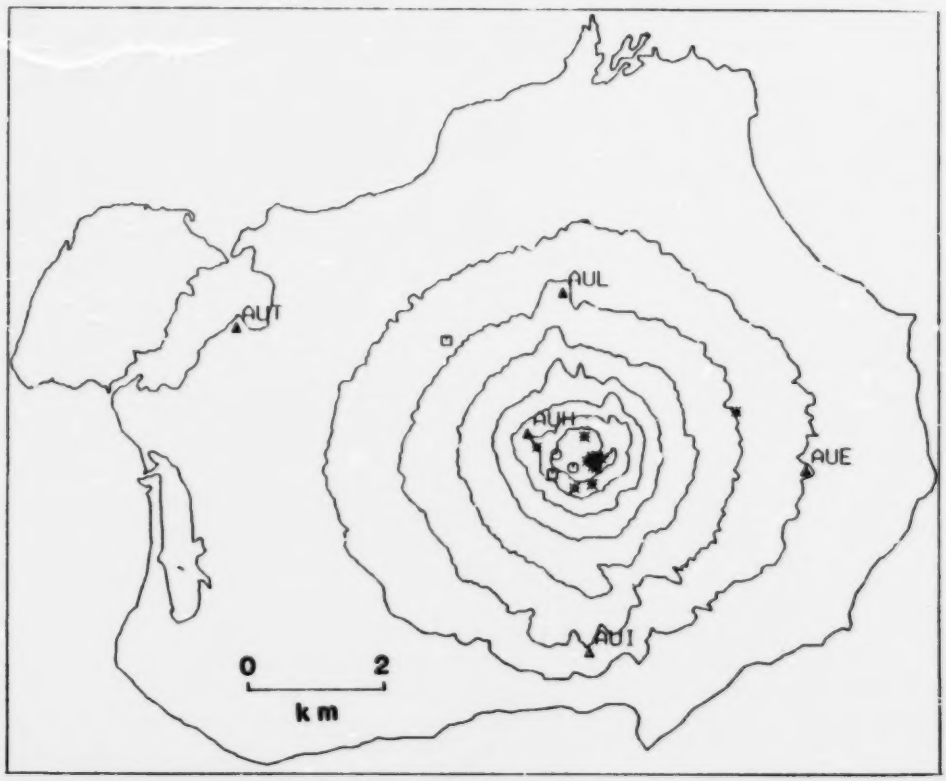

Figure 6: Map by Charlotte Power, University of Alaska, showing epicenters of the 19 best-located events 25 March-2 April. Hypocenters 0-0.5 km below the summit are shown by asterisks, 0.5-1 km by octagons, and 1-5 km by squares. The 5 seismometer stations are shown by solid triangles.

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Augustine Volcano (continued)

Tom Gosink reports that preliminary chemical analysis of ash shows that low-sulfur, high-silica, andesitic material was ejected from the 28 March eruption (table 2). The 2 April eruption was distinctly richer in silica, particularly the fine (<38 micron) material. He noted that the most chemically interesting features are found in the water soluble anions. The ash contains up to 93 ppm fluoride which may significantly affect public water supplies and epiphitic (plant) communities. Because of low snow cover this year, melt water may contain up to 10 ppm fluoride. Significant quantities of NO_3^-, up to 1500 ppm, were measured, associated almost exclusively with the fine particles. Lead was detected to only 10 ppm concentrations in all of the ash except the 2 April fine material, in which more than 80 ppm was measured. Rb/Sr is 0.07 for the 28 March bulk sample and 0.10 for the 2 April fine material.

Table 2

Date	SiO_2	Al_2O_3	Fe_2O_3*	CaO	Na_2O	MgO	K_2O	TiO_2	P_2O_5	MnO_2	total
28 March	63.51	16.10	6.55	5.78	3.08	2.37	1.33	0.81	0.34	0.11	99.98
2 April	68.1	11.9	5.7	5.2	4.6	2.4	1.2	0.46	0.28	0.09	99.93

*Total iron expressed as Fe_2O_3.
28 March - bulk sample of ash collected in Anchorage.
2 April - fine (<38 microns) fraction of ash collected in Homer.

Table 2: Chemical analyses of Augustine bulk ash samples via energy dispersive X-ray fluorescence at the University of Alaska, showing changes with time and particle size.

Information Contacts: Juergen Kienle, Tom Gosink, John Davies, John Power, David Stone, Chris Nye, Larry Gedney, and Charlotte Rowe, Geophysical Institute, University of Alaska, Fairbanks, AK 99701; Betsy Yount and Thomas Miller, Branch of Alaskan Geology, U.S. Geological Survey, 4200 University Drive, Anchorage, AK 99508; William I. Rose, Jr., Los Alamos National Laboratory, Los Alamos, NM 87545; Eliot Endo and Michael Doukas, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, WA 98661; Michael Matson, George Stephens, and Otto Karst, NOAA/NESDIS, World Weather Bldg., Camp Springs, MD 20746; Arlin Krueger, NASA Goddard Space Flight Center, Greenbelt, MD 20771.

Pavlof Volcano, Alaska Peninsula, Alaska, USA (55.42°N, 161.90°W). All times are local (= GMT - 9 hours).

On 16 April at about 1100, a Reeve Aleutian Airways pilot saw an ash and vapor plume rising from Pavlof (summit altitude 2518 m) to about 4 km above sea level. About 30 minutes later, another airplane pilot reported relatively steady ash emission to about 4.5 km altitude. Similar activity was observed around 1900.

A large eruption column that rose through low weather clouds to 14.5-16 km altitude was observed by airline pilots on 18 April at about 1620. That evening, about 0.3 cm of ash fell on Cold Bay, 55 km to the WSW. Minor ash emission was seen the next day, but weather conditions limited observations. Increased flow was reported in the Cathedral River, which drains Pavlof's NW flank.

Seismographs recorded a gradual increase in small volcanic events starting on 6 April, and a more rapid increase in seismicity 10-12 April. On 12 and 13 April, frequent discrete volcanic events were accompanied by brief (6-7 minutes or less)

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Pavlof Volcano (continued)

episodes of tremor. Preliminary inspection of later records indicated that vigorous seismicity was continuing as of 17 April, and instruments were saturated by events associated with the strong explosive activity on 18 April.

Pavlof's last reported activity began in November 1983 with vigorous explosions accompanied by strong seismicity. Occasional explosive activity continued in December, and a white vapor plume was seen from an aircraft in March 1984 (see SEAN Bulletins v. 8, nos. 10-12 and v. 9, nos. 1 and 3).

Information Contacts: Betsy Yount, Branch of Alaskan Geology, U. S. Geological Survey, 4200 University Drive, Anchorage, Alaska 99508 USA; John Taber, Lamont-Doherty Geological Observatory, Palisades, New York 10964 USA.

Mt. St. Helens Volcano, Cascade Range, S Washington, USA (46.20°N, 122.18°W).

During March, seismicity, rates of SO_2 emissions, and deformation remained at background levels. Maximum deformation rates on the dome were 1-2 mm/day, measured across the graben formed during the last extrusive event in May-June 1985. An average of 20±5 metric tons per day of SO_2 were measured in March during three overflights. Seismicity was also at background levels, although 17 small, but deeper than usual, earthquakes were located between 29 January and 1 April. These medium to high frequency events had a depth range of 3 to 8 km and epicenters trended NNW to SSE across the crater.

On 16 April at 1717, a minor gas and ash emission event sent a plume to 5.4 km above the dome. An airplane pilot reported that the cloud moved NE from the volcano. A smaller plume rose less than 2 km above the crater rim the next day at 1428. Beginning early 15 April, there had been several occasions on which brief bursts of seismicity were associated with minor (1-2 mm) dome strain episodes (measured by continuously-recording strainmeter across a zone of cracks just N of the graben), tilt excursions of a few microradians, and increases in the signal from the dome gas sensor, which detects H_2, H_2S, and SO_2. Earlier (and weaker) episodes of instrumental activity were accompanied by poor weather that prevented observation of associated emissions. Occasional deeper earthquakes, like those located in February and March, continued through mid-April, and there was no significant change in the volcano's seismic energy release. No general increase in the rate of swelling of the dome was detected before the emission of the steam and ash plumes.

No episodes of gas and ash emission had been seen since mid-May, 1985, shortly before the last lava extrusion episode (see SEAN Bulletin v. 10, no. 5). The dome sensor detected a gas pulse on 30 December 1985 after a brief earthquake swarm (see SEAN Bulletin v. 11, no. 1).

Information Contacts: Donald Swanson and Jeff Sutton, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, Washington 98661 USA; Chris Jonientz-Trisler, Geophysics Program, University of Washington, Seattle, Washington 98195 USA.

Kilauea Volcano, Hawaii USA (19.42°N, 155.27°W). All times are local (= GMT - 10 hours).

Episode 42 of the 3-year East Rift eruption of Kilauea (see last month's Bulletin) was followed by 26 days of repose, before intermittent lava spillovers from Pu'u O'o vent began on 21 March at 1330. Summit deflation began at midnight, and

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Kilauea Volcano (continued)

continuous lava production of episode 43 began at 0450 the next day. Fountains reached their maximum height of approximately 310 m at 1110. The episode ended at 1556 on 22 March after forming 2 lava flows, one extending 5 km E of the vent, the second 2.3 km to the NE toward the older Kahaualea cone. The summit grew 5 m during the eruption to 255 m above the pre-January 1983 surface.

After episode 42 the summit had inflated 12.9 microradians before the onset of episode 43 deflation. Deflation, totaling 12.8 microradians, continued until about 2 hours after the end of lava production. Inflation following episode 43 amounted to 6.3 microradians by the end of March (figure xx).

The strong tremor associated with episode 43 began at 0635 on the 22nd, peaked at 1200, and ended at 1554. Fluctuating low-amplitude tremor continued through the rest of the month near Pu'u O'o.

Addendum: By 9 April, the summit had recovered all of the deflation associated with the previous episode. Episode 44's vigorous lava production began 13 April at about 2100, after a few hours of lava spillovers into the main channel. Lava fountains reached heights of 250 m by 0200 then stopped at 0756, feeding a few short lava flows to the NE and a longer aa flow that extended more than 4 km to the ESE.

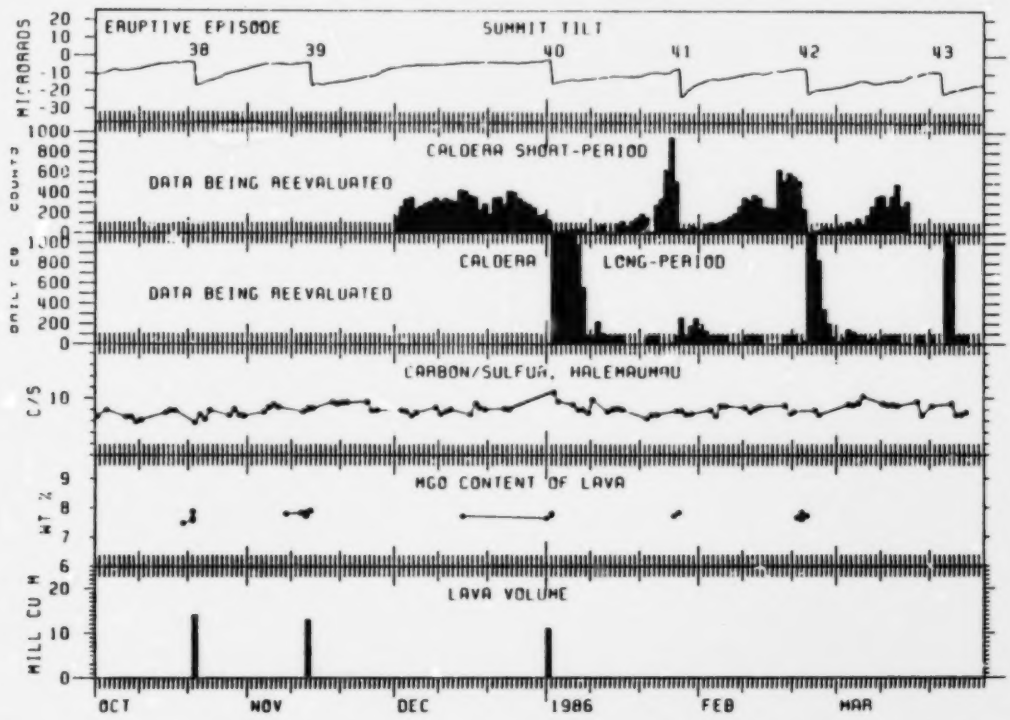

Figure 7: Six-month summary of Kilauea activity, showing summit tilt, caldera short- and long-period earthquakes, carbon/sulfur ratios of summit (Halemaumau) gases, MgO content of lava, and lava volumes. Volumes for episodes 41, 42, and 43 have not yet been calculated.

Information Contacts: Christina Heliker, Maurice Sako, and Jennifer Nakata, USGS Hawaiian Volcano Observatory, P. O. Box 51, Hawaii National Park, HI 96718 USA.

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Colima Volcano, SW Mexico (19.42°N, 103.72°W). The following is from Claude Robin and John Murray.

"Further to the report of Dartmouth College geologists (SEAN Bulletin v. 10, no. 11): According to the inhabitants of San Marcos (14 km SE of the summit), a red summit glow was seen at night in early January for the first time since 1982, together with glowing 'sparks'. At the same time people at Colima town (30 km S of the summit) observed a dark ash plume during the day, instead of the usual white condensation plume. Earthquakes were felt at San Marcos during this period.

"Claude Robin and John B. Murray visited Colima (figure 8) 1-14 February. An 8-km leveling profile set up by Murray in December 1982 was reoccupied and extended to 10 km. Results showed a slight deflation since December 1982, with stations closest to the summit (about 1.5 km distant) dropping 3.5 cm relative to the furthest stations (at 3 km from the summit), indicating a tilt of 24 microradians at this distance. This result was confirmed by 3 dry tilt stations situated at 1.5-2 km from the summit, which gave deflationary tilts of 13-45 microradians. Neither earthquakes nor harmonic tremor were detected through the level instrument (normally a fairly sensitive indicator of seismic activity) during this period, although occasional quakes were felt at night in Ciudad Guzmán (27 km NE of the summit).

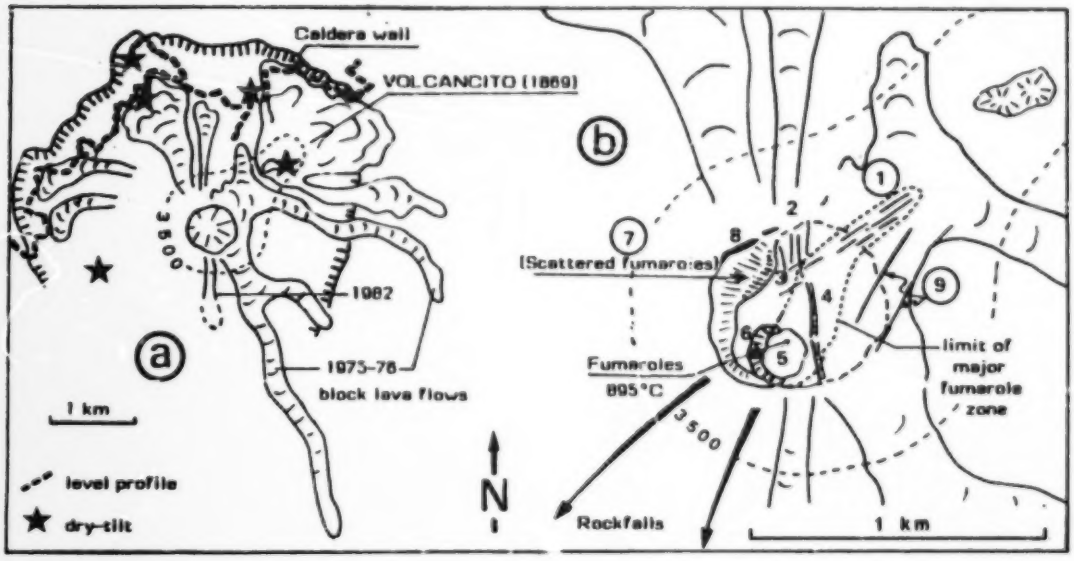

Figure 8: a) Sketch map of the summit of Colima; b) Expanded view of the summit showing geologic features.

"Volcancito Cone (about 1 km NE of the summit) was visited on 8 February, the summit was climbed for gas and sublimate collection on 11 February, and was flown over on 14 February. The fractures seen by Dartmouth College geologists in late November (fig. 8:1) were still the site of fumarolic activity, at an altitude of 3750 m (all altitudes by altimeter), but the fumarole on Volcancito had ceased to be active.

"The irregular terrain at the summit itself, corresponding to the surface of the

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Colima Volcano (continued)

andesitic dome, consists of a narrow plateau at about 3850 m. The northern slope has shallow N-S fractures 1-3 m across (fig. 8:2) with sublimate deposits, but no active fumaroles. These fractures are cut by others (fig. 8:3) trending towards Volcancito (approximately NE). A major N-S zone of weakness, 5-10 m across and very deep with strong fumarolic activity, divides the summit plateau in two (fig 8:4). According to volcanologists at the Instituto de Geofísica of the Universidad Nacional Autónoma de México, this zone was already in existence before the 1982 eruption, though perhaps less marked.

"Large numbers of summit fumarole temperatures were measured between 135° and 895°C. The high temperature was found inside a shallow 20 m pit on the SW edge of the summit plateau (fig. 8:5) perhaps an explosion pit formed in January. A red glow was detectable inside fumaroles even in bright daylight and socks were singed.

"Rockfalls from the summit dome, indicating the continued rise of the central plug, occurred down the W and SW slopes at about 15-20 minute intervals, a rate similar to that noted in December 1982 and March-April 1983. Thirty to 40 m below the summit to the W and NW are the remains of the old crater rim (fig 8:8) with a flatter shelf containing scattered fumaroles on its inside edge (fig 8:7). On photos taken from the air, two fractures trending NE (fig 8:9) are visible crossing the 1975-76 flows to the SE of the summit, but without noticeable fumarolic activity. The lowest fumarole was found at an altitude of 3600 m down the NE side of the summit cone and had a temperature of 46°C.

"From the above evidence it seems that the magnitude 8 earthquake in September (see SEAN Bulletin v. 10, no. 9) opened new fractures and accentuated previous ones on the volcano. This may have provoked some depressurization of the near-surface magma, increasing surface temperatures and fumarolic activity, and culminating in the minor ash eruptions of early January. The leveling and dry tilt data suggest no build up of magmatic pressure, and the decline in seismic activity since November also indicates that for the moment, there are no portents of a larger eruption such as those which followed the earthquakes of 1611 and 1806."

Information Contacts: Claude Robin, Laboratoire de Volcanologie, 5 Rue Kessler, 63038 Clermont-Ferrand, France; John B. Murray, "Field End", Marshall's Heath, Wheathampstead, Herts., England.

Pacaya Volcano, S Guatemala (14.38°N, 90.60°W).

Pacaya began to erupt in March 1983 and by the end of that year had built a large cone in MacKenney Crater. Lava emerged from various vents between there, an older cone to the north (Cerro Chino), and the nearby somma wall (see map in SEAN Bulletin v. 9, no. 8) through early 1985.

Alfredo MacKenney reported that between 5 May and 28 July, 1985, the two cones that had formed earlier that year (one within MacKenney Crater and the other on the east wall) had increased substantially in size because of the continuous explosive activity of moderate intensity. On two occasions (30 June and 20 July) lava flows emerged toward the N and SW. On 11 August, another crater had formed between the 2 earlier cones, which maintained strong explosive activity until 13 October. From 19 October until 10 December, renewed activity occurred from the east cone, building a perfectly-shaped cone that reached the height of Pacaya Crater (2500 m). Between 9 December 1985 and 16 February 1986, a large upper crater formed in this cone, which maintained strong constant pyroclastic explosions visible from Guatemala City (about

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Pacaya Volcano (continued)

25 km to the NNE). On 19 January a small lava dome had formed at the west base of MacKenney Crater, and from there lava flows extended N, S, and W. On 2 February, a large lava flow was moving W and on 2 March another was advancing S. As of 9 March, explosive activity continued to eject scoria and gases from the upper crater of the new cone, and lava flowed from its NW base.

Information Contact: Alfredo MacKenney, 2a Avenida 10-60, Zona 1, Guatemala City, Guatemala.

Ruiz Volcano, Colombia (4.88°N, 75.37°W).

Between mid-March and mid-April, the height of the vapor column varied between 300 and 1000 m, with SO_2 content, measured by COSPEC, of 300-1000 metric tons per day. Rates measured in early March were generally of the order of 500 metric tons per day, down from about 1000 tons per day a month earlier (see last month's Bulletin). Ash contents of the plume were low.

Seismicity during the period generally remained similar to the previous month. The number of high-frequency events declined slightly to about 3 per day, while low-frequency shocks increased somewhat to an average of 12 daily. Depths of high-frequency events were as much as 8 km (below a datum at 4.7 km altitude), with approximately 65% of the events deeper than 3 km. Epicenters were dominantly in the south part of the volcano. Around 21 March there was a small seismic crisis with 24 low-frequency and 13 high-frequency events that were associated with a small ash emission. On 6 and 7 April, two significant low-frequency events were registered, but they were not accompanied by any other activity. Colombian geologists noted that regional earthquakes could have had some influence on the increase in low-frequency seismicity.

During the second week in April, data from electronic distance measurement (EDM) lines revealed slight deflation (of the order of 1 mm per day) at stations on the N and E sectors of the volcano. In contrast, a station in the SW sector (CISNE), indicated an inflation of about 3 mm daily during the same period. Dry and electronic tilt measurements have not shown significant changes. Rates of movement of ice near the summit have slowed since January to less than half the December rates.

Information Contacts: Alberto Núñez and Fernando Muñoz, Observatorio Vulcanológico de Colombia (INGEOMINAS-UNICALDAS); Piso 11, Edificio Leonidas Londoño, Apartado Aereo 01296, Manizales, Colombia.

Piton de la Fournaise Volcano, Réunion Island, Indian Ocean (21.23°S, 55.71°E). All times are local (= GMT + 4 hours).

Eruptive activity resumed 19 March, after less than 6 weeks of quiet. This sixth episode of the eruption that began 14 June 1985 included the first lava production outside the Enclos caldera since 1977.

Pre-eruption seismicity and deformation

The first half of March was characterized by weak seismicity. On the 17th, intermediate-depth events began, centered 3 km below the summit. During the night and the next day, 7 events were recorded, all at the same depth, E of the summit zone. A seismic crisis began suddenly at 2246 and lasted 30 minutes without an

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Piton de la Fournaise Volcano (continued)

eruption. All of the events were shallow and centered under the summit crater. A tiltmeter on the SW flank of Bory crater and an extensiometer inside the crater recorded a sudden movement at 2245-2255 related to this intrusion. A 300-microradian inflation of the E portion of Dolomieu crater was measured by the 2 tilt stations E of the summit area. Geodetic measurements between the Enclos caldera and the summit showed a NW displacement of the E wall of Dolomieu. No movement was recorded within the caldera.

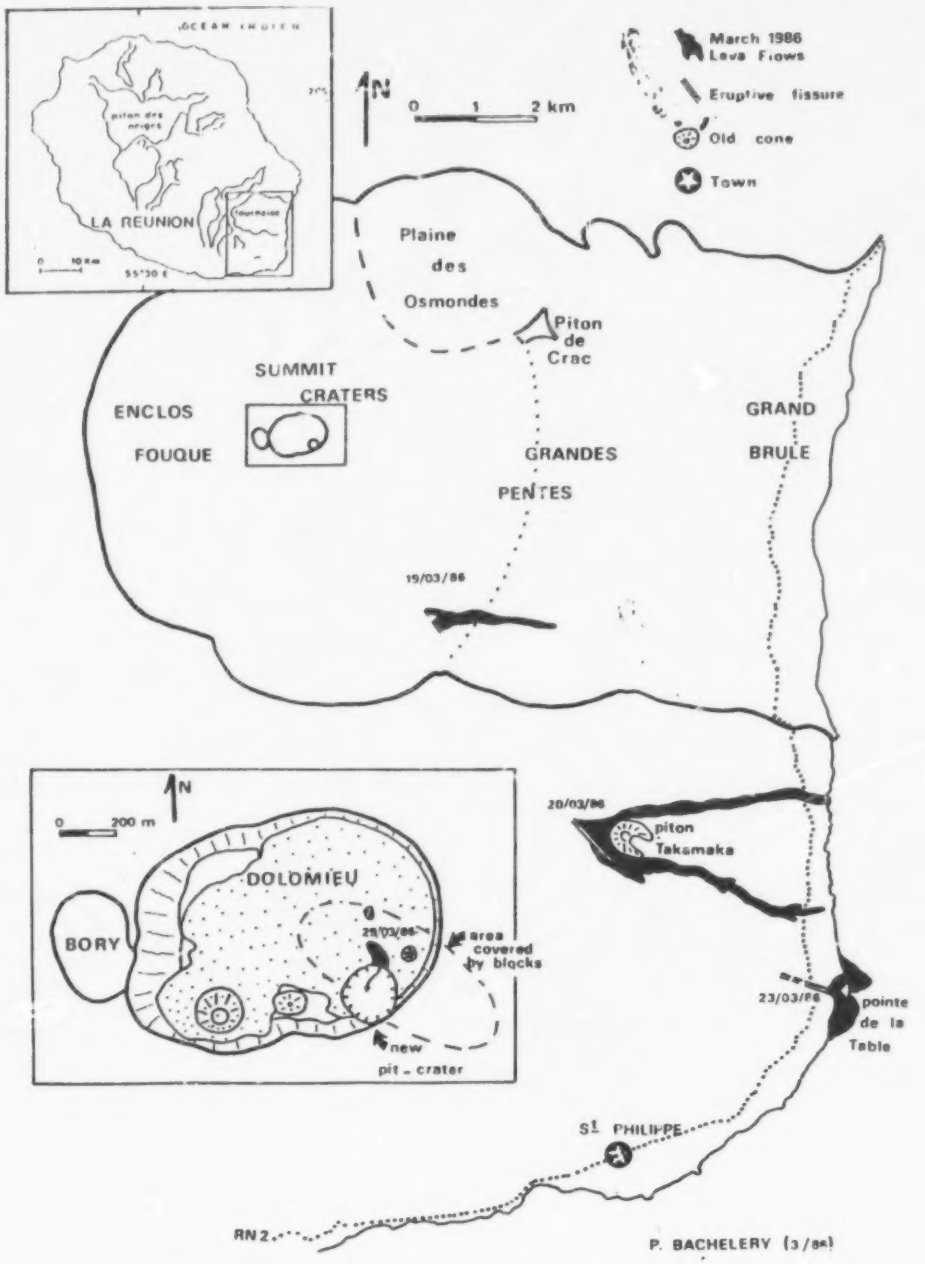

Figure 9: Map, courtesy of P. Bacheléry, showing the March 1986 eruption fissures and lava flows, and the new summit pit crater.

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Piton de la Fournaise Volcano (continued)

SE caldera eruption, 18-19 March

Significant seismic activity during the night of 18-19 March followed the intrusion and preceded fracturing that began in the S part of the caldera at 0500. An eruption began at 0640 in the SE part of the caldera (at the bottom of Nez Coupé du Tremblet; figure 9), producing lava fountains and a small flow from the 120°-trending fissure. The volume of lava erupted was low, and this phase ended at 1520. The seismic crisis, however, continued during the effusive activity, with both deep (3-5 km) and summit events.

Upper Flank Eruption, 20-22 March

On 20 March at 0020 a weak tremor was recorded in the S part (near the Nez Coupé du Tremblet station), and outside the caldera. Observation of glowing lava was possible only during pre-dawn hours because of poor weather conditions and dense vegetation. Tremor increased during the night, and another 120°-trending fissure, 600 m long, opened outside the caldera at 1000 m altitude (just above Piton Takamaka; figure 9). At 0900, authorities evacuated 250 inhabitants. Two lava flows issued from the fissure, cutting the main circum-island road (RN 2) in the afternoon (at 1500 and 1700) of the 20th. One moved N of Piton Takamaka and reached the sea the next day. The second flow passed S of Piton Takamaka, stopping 200 m from the sea. Significant seismic activity continued in the summit area during the flank eruption. Lava destroyed 8 houses, leaving 51 people homeless. The lavas are olivine basalts with a small amount of 1-4 mm olivine phenocrysts. Effusive and seismic activity continued at a high level through 21-22 March.

Lower flank eruption, 23-29 March

Seismicity increased on the 23rd at 0000, with numerous shallow seismic events in the summit area. More than thirty magnitude 1.5-2.7 shocks were recorded during the night. At 0900 a fissure opened in the circum-island road S of the volcano at less than 100 m altitude (near Pointe de la Table) initially emitting only water vapor. At about 1600, the fissure apparently began to extend downslope into thick forest. At 1700, very viscous lava emerged from 3 vents (in the forest) at an altitude of 30 m. A levelling network established around the fissures showed the progressive emplacement of a shallow dike. A new tilt station 1 km away from the fissures did not record any movement.

The opening of the main fissures across the road reached 105 cm on 23 March (70 cm during the first 5 hours). After the onset of lava production, the width of the main fissure decreased by 9 cm, but widening resumed, reaching 129 cm on the 27th and 167 cm on the 31st. Right-lateral movement accompanying the opening of the fissures was measured at 41.5 cm the first day and 49.7 cm by the 31st.

During the night of 23-24 March, more vigorous activity took place between Pointe de la Table and the circum-island road. Predominantly pahoehoe lava emerged from lava tubes and cascaded into the sea at 2 points near Pointe de la Table. On the 24th seismicity decreased and was limited to the summit zone. Effusive activity stopped on the upper flank fissure (near Piton Takamaka) that had begun to erupt on 20 March, but significant degassing continued. Activity from the lower flank fissures was strongest on 24 March at about 1400. Outflow rates on the 24th exceeded 7 m^3/second and lava temperature was 1160°C. By the time lava production stopped on 29 March at 0100, 3-4 x 10^6 m^3 of lava had built a very flat 30-hectare platform along the shore that contained many lava tubes. The lava front in the sea was about

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Piton de la Fournaise Volcano (continued)

1.5 km wide, and its maximum seaward extension was 150-200 m. The volume of degassed magma was about 5 x 10^6 m^3. This flow was less olivine-rich than the Takamaka lava.

Summit eruption and Pit Crater Formation, 29 March-5 April

On 28 March at 1000 a new seismic crisis began, with tremor on the dome at 1110-1120. The seismic crisis was limited to the summit area and lava emission stopped outside the Enclos caldera. No deformation had affected the summit area during the 20-28 March period, but on the 29th at 1030-1600, the tiltmeter on the SW flank of Bory crater recorded progressive summit deflation of 23 microradians. Seismicity changed at midday to tremor-like activity. At 2238 a phreatic explosion began in Dolomieu crater and minor fountaining occurred from a fissure in its SE sector. By early the next morning collapse had formed a pit crater 100 m in diameter and 80-100 m deep. Degassed lava emerged from just below one edge, perhaps from a sill or still-molten 29 December lava, forming a 5-m-wide cascade that drained back into the bottom of the newly-formed pit crater.

On the 30th a general deflation of 35-350 microradians of the summit area occurred, centered on the SE part of Dolomieu crater. This deflation was not detected by the Enclos tilt stations. The summit lava flow stopped around 5 April.

Magnetic data

Beginning in mid-1985, a permanent magnetic network has been maintained on the volcano. Four stations telemetered to the observatory: Bory crater (BOR), the N flank of the dome (PMC), the W part of the Enclos caldera (CSR), and the observatory (PDC), with a 1-minute sampling frequency of the earth's magnetic field. The time variations of the simultaneous differences are studied with CSR as the reference station. Several days before the first seismic crisis (17 March), a slow decrease in the differences appeared, about 2 nanoteslas (nT) per 10 days. Early in the seismic crisis of 17 March, a sharp decrease in the differences was observed (about 3.5 nT and 2 nT for CSR and BOR). Similar variations were observed on the 29th when the seismic crisis preceded pit crater formation. By 3 April, after the eruptive episode, no variations were no longer observed.

Information Contacts: Hughes DeLorme, Jean-François DeLarue, J. C. Delmond, J. Hoarau, A. Hirn, J. C. Lepine, J. Zlotnicki, Robin (IGN), Hakenholtz (EDF), Maison (TAAF), and DuPont (ONF) Observatoire Volcanologique du Piton de la Fournaise, 14 R.N. 3, 27ème km, 97418 La Plaine des Cafres, Réunion Island; P. Bachelery, Laboratoire de Géologie, Université de la Réunion, Réunion Island; P. M. Vincent and A. Bonneville, Université de Clermont, 63038 Clermont-Ferrand Cedex, France; J. L. Le Mouel, J. L. Cheminée, P. A. Blum, and G. Brandeis, Direction des Observatoires Volcanologiques, Institut de Physique du Globe, Tour 14, Université de Paris VI, 4 Place Jussieu, 75230 Paris Cedex 05, France; Maurice Krafft, Centre de Volcanologie Vulcain, B. P. 5, 68700 Cernay, France.

Mt. Erebus Volcano, Ross Island, Antarctica (77.58°S, 167.17°E). The following is from Philip Kyle.

"Mt. Erebus has been in a continuous eruptive phase since 1972, when a small anorthoclase phonolite lava lake was discovered. From 1972 until about 1976 the lava lake expanded to a semi-circle about 60 m in diameter (figure 10, left). There was little change until 13 September 1984, when a significant increase in activity

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Mt. Erebus Volcano (continued)

occurred, peaking during September and early October but remaining at significantly higher levels than the preceding 12 years until January 1985 (see SEAN Bulletins v. 9, nos. 9-10 and v. 10, no. 3). Previously, small strombolian eruptions, which occurred 2-6 times per day, had occasionally ejected bombs from the 220-m-deep inner crater floor onto the main crater rim. During the increased activity, bombs averaging 2 m long and reaching more than 10 m in length were dispersed radially around the crater rim, reaching 1.2 km (horizontally) from the center of eruption in the inner crater. The eruptions were witnessed from 60 km distance and the explosions could be heard from 25 km.

"Inspection of the volcano in October, November, and December, 1984 showed that the lava lake was gone (figure 10, center). An initial interpretation (see SEAN Bulletins v. 9, no. 11 and v. 10, no. 3) was that the lava lake had frozen over and was domed up. However, observations in December 1985 suggest that the inner crater was partially filled with ejecta from the eruptions.

"By December 1985, the inner crater showed some resemblance to its morphology and form prior to September 1984 (figure a, right). A small lava lake, about 15 m in diameter, was in a site similar to that of the former lake. The elevation of the new lake was not measured, but it appeared similar to the 1983 lake. The active vent, a small explosion crater adjacent to the lava lake, had re-formed and a small crater was seen around the site of a fumarole that had been active prior to September 1984. The overall impression of the activity was that the magma column height and position had not changed significantly for the past 14 years. The late 1984 eruption partially filled the inner crater with ejecta that obscured the magma column. Since then, the ejecta have been assimilated back into the magma column or ejected by small eruptions from the lava lake and active vent.

"Ground-based COSPEC SO_2 flux measurements made on 17 December 1985 showed cyclic variations from 5-20 metric tons per day, with a period of about 2 1/2 hours. The average SO_2 flux was about 12-15 metric tons per day. Seismicity during 1985 was variable (figure 11), showing high levels from mid-February to early April and throughout June and July. From August to December, the activity was extremely quiet."

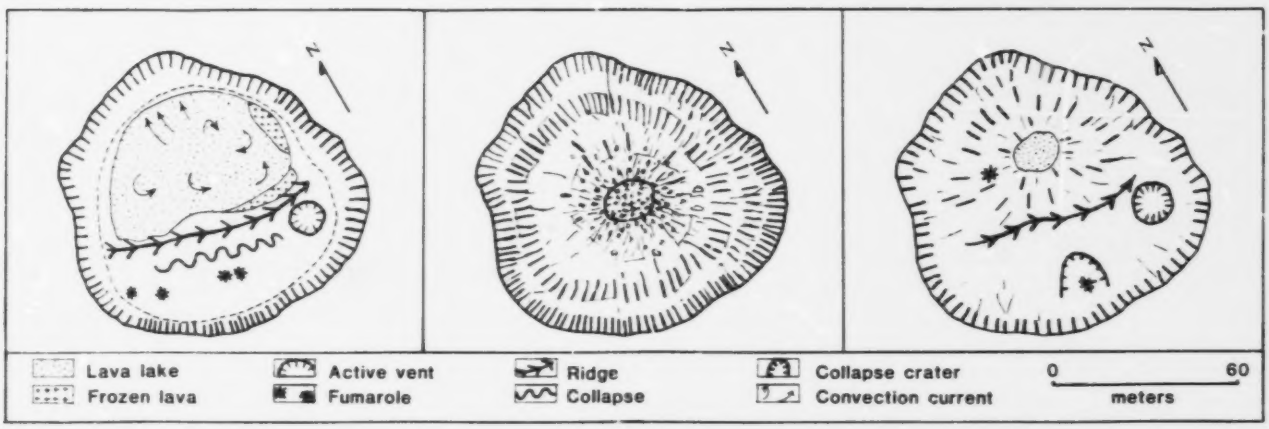

Figure 10: Sketch map showing the inner crater in January 1984 (left), November 1984 (center) and December 1985 (right), courtesy of Philip Kyle.

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Mt. Erebus Volcano (continued)

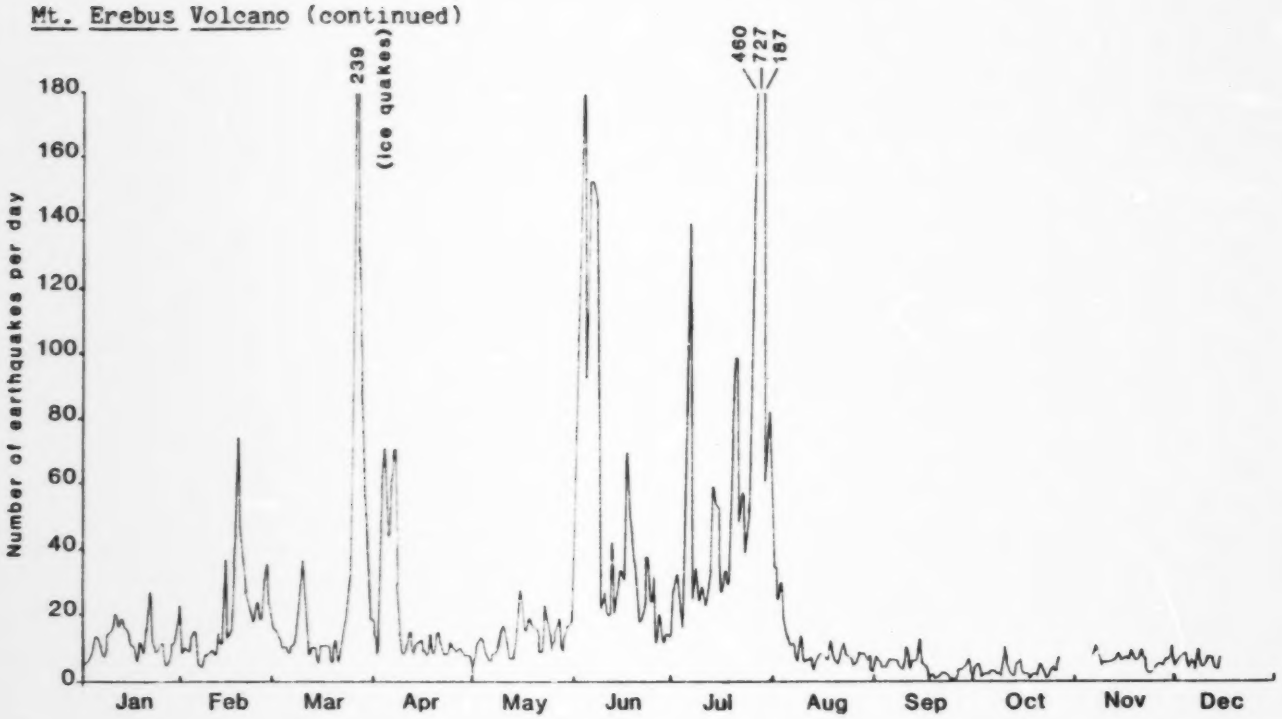

Figure 11: Number of local earthquakes per day recorded by the seismometer at Hooper Shoulder in 1985, courtesy of K. Kaminuma.

Information Contacts: Philip R. Kyle, Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801 USA; K. Kaminuma, National Institute of Polar Research, 9-10 Kaga, 1-Chome, Itabashi-ku, Tokyo 173, Japan.

Sangeang Api Volcano, Lesser Sunda Islands, Indonesia (8.18°S, 119.06°E).

"Sangeang Api volcano continues in eruption. By comparison with activity in December and January, the frequency of small explosions increased slightly during February and March to about 80 per day. The height of the eruption clouds averaged about 900 m. Since December 1985, no visits have been made to examine the 1985 lava flow, but continued lava production is suspected."

Information Contacts: Olas, Adjat Sudradjat, and Tom Casadevall, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Tangkubanparahu Volcano, West Java, Indonesia (6.77°S, 107.60°E). All times are local (= GMT +7 hours).

"Fumaroles of the Kawah Baru field continued to have elevated temperatures that ranged from 152° to 158°C during March. Seismic tremor was recorded on the seismometer at Kawah Ratu on 17 March, from about 0900 until 2400. Tremor was again recorded briefly on 18 and 19 March.

"During March the complete EDM network was reoccupied for the first time since 1983. The results of the survey are consistent with long term inflation of Tangkubanparahu as detected by spirit level tilt measurements from 1981 through

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Tangkubanparahu Volcano (continued)

January 1986. The center of inflation as determined by tilt measurements is located at Kawah Upas, about 1/2 km E of the Kawah Baru fumaroles. The epicentral area of the late 1983 seismic activity was in the S half of Kawah Upas, approximately coincident with the center of uplift determined from tilt measurements."

Information Contacts: Kaswanda, Harun Said, Adjat Sudradjat, and Tom Casadevall, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Lokon-Empung Volcano, North Sulawesi, Indonesia (1.358°N, 124.792°E). All times are local (= GMT + 8 hours).

"Activity began 22 March at 0336 with a small phreatic eruption from the Tompaluan crater, elevation 1140 m, located in the saddle between Lokon and Empung cones. A small (700,000 m^3) crater lake within Tompaluan crater was about 60% evacuated during the eruption of 22 March. A larger, phreatomagmatic eruption occurred on 24 March at 0343, emptying the remainder of the lake and throwing out incandescent ballistic blocks to heights of 800-1000 m. Mud flows were produced during both eruptions. No casualties or damage have been reported. Small explosions occurred on 29 March at 1547 to 250 m height, at 1806 to 300 m, and at 1817 to 200 m. The VSI observation post is located at Kakaskasen, about 5 km SE of the volcano. The observatory has one vertical component seismometer, located at Lokon."

More than a dozen moderate eruptions have been documented at Lokon-Empung since the early 19th century, all from Tompaluan Crater, where activity was last reported in late 1979. The crater lake formed after the May 1969 eruption. Pyroclastic flows were reported in 1970. Larger eruptions from Empung Crater occurred between 1350 and 1400, and between 1750 and 1800.

Information Contacts: Suratman, Adjat Sudradjat, and Tom Casadevall, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Volcanic Activity in Papua New Guinea

The following is from the Rabaul Volcano Observatory.

Manam Volcano, Bismarck Sea (4.10°S, 145.06°E).

"Activity at Manam continued at a low level until mid-February, with the main and southern craters releasing a thin white vapour plume. Heavy rainfall after the 14th (up to 80 mm/day) produced a grey-to-brown ash-laden plume that was forcefully but silently released from the southern crater (14-20 and 24 February). These emissions often followed a regular pattern, lasting 20-30 minutes with repose periods of 3-5 minutes. Thick plumes rose as much as 900 m above the crater before being carried away by NW winds. Light ashfalls were reported on the downwind side of the island until the end of the month.

"The activity produced no explosion shocks but did generate some weak harmonic tremor. There was otherwise no noticeable change in the seismicity, which remained at a non-eruptive level (1200-1700 low-amplitude B-type events daily) throughout February. The Tabele water tube tiltmeters (about 4 km SW of the summit) showed 5 microradians of radial inflation during the month.

"A very weak level of activity prevailed throughout March. The main and southern craters released weak-to-moderate grey and brown emissions. Low roaring

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Manam Volcano (continued)

sounds were occasionally heard (13, 18, and 19 March). Occasional very light ashfalls were reported on the downwind side of the island.

"The seismicity remained at an inter-eruptive level (100-1800 small B-type events per day) throughout March. No changes were recorded by the Tabele water tube tiltmeter.

Bagana Volcano, Bougainville Island, Solomon Islands (6.14°S, 155.19°E).

"The phase of stronger extrusive activity which began on 16 February (see last month's Bulletin) continued into March, and was detected both seismically and visually. There were occasional reports of moderate-to-strong white-to-dark brown emissions from the summit, which displayed a weak glow whenever visible at night.

"The seismicity, which increased sharply in mid-February, declined slightly during the first week of March, but rose again steadily to a peak of 145 B-type events per day on the 12th before gradually declining to about 20 events per day at month's end."

Langila Volcano, New Britain Island (5.53°S, 148.42°E).

"Activity at Crater no. 2 in March was slightly higher than in February. Moderate-to-strong white-to-grey emissions were released intermittently throughout the month. Light ashfalls were reported 10 km downwind on 4 and 14 March. Weak night glows (with intermittent incandescent ejections) were reported on 16, 24, and 25 March. Explosion and rumbling noises were heard on the 4th, 9th, 14-16th, 18th, and 24-30th. Seismicity was at a moderate level with 2-10 vulcanian explosion events per day."

Rabaul Caldera, New Britain Island (4.27°S, 152.20°E).

"Seismicity remained at a moderate level during March, with 223 recorded events (compared to 72 in January and 317 in February). Ground deformation measurements, however, showed only minor tilt and EDM changes in both the Greet Harbour and Vulcan areas."

Information Contact: Peter Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Volcanic activity in Vanuatu

Richard Stoiber visited Yasour on 4 March, landed briefly on Ambrym 8 March, and flew over Lopevi the same day. He provided the following report.

Yasour Volcano, Tanna Island (19.52°S, 169.43°E).

"There were 3 aligned craters, perhaps 300 m apart. On 4 March, heavy fumarolic activity occurred from the northernmost crater. Frequent noisy strombolian activity ejected tephra to heights of tens of meters from the other two craters. Tephra did not rise above the volcano's summit."

Yasour has been in continuous eruption since visited by Captain Cook in 1774.

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Ambrym Volcano, Ambrym Island (16.25°S, 168.08°E).

"On 8 March an ash-laden plume issued from Ambrym and reached an altitude estimated at 3000 m (by aircraft altimeter), remaining visible 30 km or more downwind. The volcano's last violent activity had been reported 3 months earlier."

More than 25 eruptions have been reported from Ambrym since the mid 19th century. During a year of intense strombolian activity in 1950-51, 8 x 10^8 m^3 of tephra were ejected.

Lopevi Volcano, Lopevi Island (16.51°S, 168.35°E).

"A small white vapor plume was being emitted from the crater on 8 March. The most active fumaroles were high on the cone."

About 20 eruptions from Lopevi have been described in the past 120 years. The last reported activity was the ejection of a large ash cloud in October 1982 (see SEAN Bulletin v. 7, no. 10).

Information Contact: Richard Stoiber, Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire 03755 USA.

Sakurajima Volcano, Kyushu, Japan (31.58°N, 130.67°E).

Eight explosions from the summit crater of Minamidake were recorded in February and 13 in March (table a). The explosions caused no damage. The maximum ash cloud height was 1500 m above the crater. Bursts of microearthquakes, typical of Sakurajima, occurred on 10, 11, 23, and 31 March. Sakurajima's eruption began in 1955; see SEAN Bulletin v. 11, no. 1 for a summary of its activity since then.

TABLE 3: Explosions at Sakurajima

Date: March	6	11	12	20	22	23	25	26	27	29	31	Total
Number:	1	1	2	1	1	2	1	1	1	1	1	13

Information Contact: Office of Volcanic Observations, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Fukutoku-oka-no-ba Volcano, Volcano Islands, Japan (24.28°N, 141.52°E).

A submarine eruption started 18 January, building a new 700-m island by the 20th (see the last 3 SEAN Bulletins). Frequent vigorous explosions continued on 20 and 21 January, then activity declined to water discoloration, seen on every overflight in February and March. Wave action gradually eroded the island, and personnel from the Japan Maritime Safety Agency reported that it was entirely below sea level by the time of their overflight on 26 March.

Information Contacts: Same as for Sakurajima; and Japan Maritime Safety Agency, 5-3 Tsukiji, Chuo-ku, Tokyo 104, Japan.

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Atmospheric Effects

On 18-19 January, lidar operated by the University of Bonn at the Andoya Rocket Range, Norway (69.28°N, 16.02°E) detected strong layers to 24.5 km that were not present during their previous observation on 30-31 December. Stratospheric aerosols were less conspicuous the next night and little aerosol material was evident the nights of 20-21 and 21-22 January, and the morning of 1 February. Strong layers to almost 26 km were observed again the night of 2-3 February. Lidar data from Garmisch-Partenkirchen, Germany (47°N, 11°E) showed no apparent new aerosols until 4 January, when a layer was detected at 26.4 km. Backscattering ratios were largest 21, 22, and 26 January for layers centered from 17.4-21 km, but enhanced values at similar altitudes continued to be observed through February, including a 24-km layer on the 22nd (table a). The source of these high-latitude aerosols was uncertain, but may have included material from both the 13 November 1985 eruption of Ruiz Volcano, Colombia (see SEAN Bulletins v. 10, nos. 10-11) and vigorous late-1985 explosive activity from Kliuchevskoi Volcano, Kamchatka (see SEAN Bulletins v. 10, nos. 11-12). Aerosols had also been detected in January at high northern latitudes by a NASA airborne mission (see SEAN Bulletin v. 11, no. 1).

At lower latitudes, new stratsopheric aerosols have been present since shortly after the Ruiz eruption. At Mauna Loa, Hawaii (19.5°N, 155.6°W) lidar data showed a series of small sharp peaks between 16.5 and 26 km on 5 March (table 4 and figure 12). The layer centered at about 20 km altitude strengthened later in the month, dominating the profile 20 and 28 March. A layer at about 23 km, not evident on 12 March, was seen on 20 and 28 March, and a broad zone of enhanced backscattering at 28-35 km was present on 28 March. From Fukuoka, Japan (33.65°N, 130.35°E), lidar continued to detect a layer centered at 18.4 km altitude on several nights in March, as during much of December (see SEAN Bulletin v. 10, no. 12). A very sharp peak was measured at 22 km on 11 March, was weaker but still present on 24 March, and sharp peaks were present at 21.4 and 25.1 km during the next observation on 31 March.

Robert Malmström reported that sunsets at La Palma, Canary Is. (28.75°N, 17.88°W) appeared similar to one another 9-21 January, but the sky was distinctly more pink on the 23rd (about 1945 GMT) and 24th. On 30 January there was a very strong pink glow, again at about 1945 GMT, that was reminiscent of sunsets seen after the El Chichón eruption.

Table 3: (next page) Lidar data from various locations, showing altitudes of aerosol layers. Note that some layers have multiple peaks. Backscattering ratios from Fukuoka, Japan are for the Nd-YAG wavelength of 1.06 microns; all others are for the ruby wavelength of 0.69 microns. An explanation of the relationship of ruby and Nd-YAG values is on p. 15-16 of SEAN Bulletin v. 9, no. 10. Integrated values show total backscatter, expressed in steradians^{-1}, integrated over 300-m intervals from 16-33 km at Mauna Loa and from the tropopause to 30 km at Hampton. Altitudes of maximum backscattering ratios and coefficients are shown for each layer at Mauna Loa; maxima were at the same altitudes 12, 20, and 28 March. The 23 December-26 January data from Garmisch-Partenkirchen replace preliminary values in SEAN Bulletin v. 11, no. 1, and the 5 March data from Hampton replace preliminary values in last month's Bulletin.

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Atmospheric Effects (continued)

TABLE 4

LOCATION	DATE	LAYER ALTITUDE IN KM (peak in parentheses)		BACKSCATTERING COEFFICIENT	RATIO	INTEGRATED
Garmisch-Partenkirchen	23 Dec.	11-27	(13.8)		1.4	
Germany (47°N, 11°E)	4 Jan.	11-29	(16.8)		1.4	
			(26.4)		1.4	
	21 Jan.	12-28				
		16-19	(18.6)		1.9	
		20-22.5	(21.0)		2.4	
	22 Jan.	10-29				
		13-19	(18.0)		1.8	
	26 Jan.	12-26				
		15-18.5	(17.4)		1.8	
	28 Jan.	13-29				
		15.5-18.5	(17.4)		1.5	
		18.5-21	(19.8)		1.5	
	4 Feb.	11-30				
		16.5-19	(17.4)		1.4	
	16 Feb.	11-?				
		15.5-20	(16.8)		1.4	
			(19.2)		1.3	
	22 Feb.	11-27	(16.2)		1.3	
			(20.4)		1.3	
			(24.0)		1.4	
	27 Feb.	13-28	(13.8)		1.3	
			(16.2)		1.2	
			(21.0)		1.2	
Mauna Loa, Hawaii	5 March	16.5-26	(19.5)	0.32×10^{-7}	1.7	0.16×10^{-3}
(19.5°N, 155.6°W)			(20.4)	0.28×10^{-7}	1.7	
			(22.5)	0.16×10^{-7}	1.6	
			(24.3)	0.15×10^{-7}	1.7	
	12 March	16.5-22.5	(20.1)	0.26×10^{-7}	1.6	0.12×10^{-3}
	20 March	16-24	(20.1)	0.47×10^{-7}	2.1	0.14×10^{-3}
			(23.4)	0.11×10^{-7}	1.5	
	28 March	17-25	(21.0)	0.39×10^{-7}	2.1	0.15×10^{-3}
			(22.5)	0.16×10^{-7}	1.6	
		28-35	(27.9)	0.06×10^{-7}	1.5	
			(30.6)	0.04×10^{-7}	1.6	
Hampton, Virginia	5 March	10-25	(16.7)		1.4	0.22×10^{-3}
(37.1°N, 76.3°W)						
Fukuoka, Japan	4 March	13.0-21.5	(18.4)		2.34	
(33.65°N, 130.35°E)	7 March	13.0-21.5	(17.6)		2.74	
	11 March	15.0-23.0	(18.4)		1.78	
			(22.1)		3.18	
	24 March	13.5-22.5	(22.1)		2.25	
	31 March	16.0-25.0	(18.4)		2.06	
			(21.4)		2.27	
			(25.1)		2.48	

Information Contacts: H. Jäger, Fraunhofer-Institut für Atmosphärische Umweltforschung, Kreuzeckbahnstrasse 19, D-8100 Garmisch-Partenkirchen, West Germany; U. von Zahn, Physikalisches Institut, Universität Bonn, Nussallee 12, 5300 Bonn 1, West Germany; Thomas DeFoor, Mauna Loa Observatory, P. O. Box 275, Hilo, Hawaii 96720 USA; William Fuller, NASA Langley Research Center, Hampton, Virginia 23665 USA;

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Atmospheric Effects (continued)

Motowo Fujiwara, Physics Department, Kyushu University Fukuoka 812, Japan; Robert Malmström, Gaildorferstrasse 27, D-7000 Stuttgart 50, West Germany.

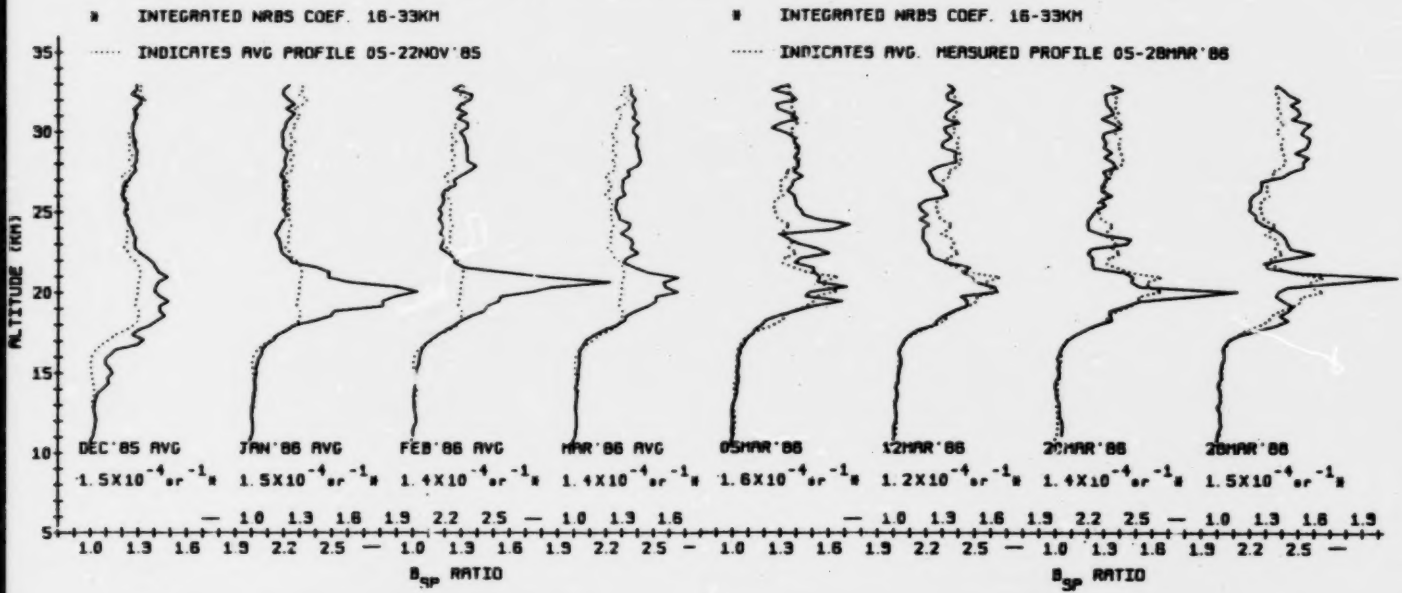

Figure 12: Lidar profiles from Mauna Loa, Hawaii (19.5°N, 155.6°W) 5-28 March, courtesy of Thomas DeFoor. The dotted line superimposed on each profile represents the average March data.

Figure 13: Average monthly lidar profiles at Mauna Loa, Hawaii, December 1985-March 1986 courtesy of Thomas DeFoor. The dotted line superimposed on each profile represents the average 5-22 November 1985 data, before the arrival of new aerosols over Hawaii.

EARTHQUAKES

DATE	TIME (GMT)	MAGNITUDE	LAT.	LONG.	DEPTH OF FOCUS	REGION
24 March	1932	Ms 6.8	2.52°S	138.73°E	shallow	Irian Jaya, Indonesia
30 March	0854	Ms 5.8	26.23°S	132.70°E	10 km	Central Australia

There were no reports of damage or casualties for the 24 March earthquake.

A field survey in the epicentral region of the 30 March earthquake led to the discovery of an arcuate fault convex to the NE in the Marryat Creek (N-central South Australia) region. Maximum throw was 0.6 m and faulting extended for at least 7.5 km. The nearest population is 35 km from the epicenter and there were no reports of damage or casualties.

Information Contacts: National Earthquake Information Service, U. S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225 USA; Director, Bureau of Mineral Resources, B.M.R. Building, Constitution Avenue, Canberra, A.C.T., Australia.

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FIREBALLS

NW Australia, 20 March, 0755 GMT (1555 Western Australia Standard Time).
Observer: Captain G. Bardsley, Ansett West Australia, Flight MV 395 (Darwin to Perth)
Location: 15.77°S, 128.70°E, aircraft course 220° magnetic
First sighting: 195° magnetic, 70-80° above horizon
Last sighting: 150° magnetic, 45-50° above horizon
Duration: 2 seconds
Magnitude: Brighter than Venus, seen 2 hours before sunset
Color: Yellow-lime green
Trail: None
Termination: No fragmentation reported

Information Contact: Colin Keay, Physics Department, Newcastle University, N.S.W., 2308, Australia.

England, 17 March, 2137 GMT.
Observer: P. M. Bagnall
Location: Wallsend, Tyne and Wear (55.00°N, 1.31°W)
First sighting: R.A. 15h 00m, declination +45°
Last sighting: R.A. 17h 00m, declination +52°
Duration: 2.5-3 seconds
Magnitude: -8 increased to -10
Color: Bright green with yellow halo; fragments green and white
Trail: Dusty, contained white fragments
Termination: Fragmented after 2 seconds
Sounds: None heard

Information Contact: Robert A. Mackenzie, Director, British Meteor Society, 26, Adrian Street, Dover, Kent CT17 9AT England.

Yugoslavia, 19 March, 0423 GMT.
Observers: Captain De Bruijn, First Officer M. Oeler, Flight Engineer M. Slumka of Lufthansa LH 635 (Istanbul-Frankfurt)
Location: 44.20°N, 20.00E (WNW of Belgrade), aircraft course 305° magnetic, altitude 10.6 km
First sighting: Azimuth 310° magnetic, altitude 10°
Last sighting: Azimuth 335° magnetic, altitude -1°
Duration: 3-4 seconds
Magnitude: Like a big silvester rocket
Termination: Fragmented

Information Contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

SW Canada/NW USA, 19 February 0520 GMT (18 February 2120 Pacific Standard Time). The following report suppliments the report on this fireball in last month's Bulletin.
Observers: Gary Harland, William Burnyeat, David Dodge
Location: Vancouver, British Columbia (49.276°N, 123.141°W)
Path: Travelled from Regulus toward Polaris, generally SE to NW
Magnitude: -8
Color: Magnesium blue
Train: Red
Termination: Extinguished between ε and λ/ϕ Ursa Majoris

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Canada/USA (continued)

Sounds: None heard

The fireball was also seen by many hundreds of people from Oregon and Washington, USA as well as other parts of British Columbia. All of the observations are similar to that reported above with the notable exception of sound. Nearly every observer outside the city of Vancouver heard a sonic boom with the fireball or up to 2 minutes after it had passed. The fireball probably crossed the Canada/USA border near the 120th meridian and extinguished over the 121st meridian at a latitude of 51°N.

Information Contact: David Dodge, Gordon Southam Observatory, 1100 Chestnut Street, Vancouver, British Columbia, V6J 3J9, Canada.

NW Arizona, USA, 9 April, 0700 GMT (0000 Mountain Standard Time).
Observer: Jim Speiser
Location: Fountain Hills, Maricopa County (33.3°N, 112.0°W)
Path: ENE to NE, altitude 10-15°
Magnitude: Cast shadows
Color: Green
Trail: Blue
Train: None
Termination: No fragmentation, vanished above horizon
Sounds: None heard

Information Contact: Jim Speiser, 14634 Fountain Hill Boulevard, Fountain Hills, Arizona 85268 USA.

Florida, USA, 18 March, 0114 GMT (17 March, 1914 Eastern Standard Time).
Observer: Barbara Mae Christy
Location: St. Augustine, Johns County (29.54°N, 81.19°W)
Path: S to N through Big Dipper handle, parallel to horizon, altitude 70°
Duration: 4-5 seconds
Magnitude: Brighter than the full moon, cast no shadows
Apparent size: 1/4-1/2 the diameter of the full moon
Color: White-yellow
Trail: Deep russet, did not persist after fireball passed
Termination: Disappeared above horizon

Information Contact: Barbara Mae Christy, 5037 Linette Lane, Annandale, Virginia 22003 USA.

Central and Western Oregon, USA, 16 March, 0600 GMT (15 March, 2200 Pacific Standard Time). Several reports are summarized.

Location: Camp Hancock, Wheeler County (44.85°N, 120.47°W)
First sighting: Azimuth 0°, altitude 22°
Last sighting: Azimuth 355°, altitude 12°
Termination: Disappeared above horizon

Location: Keiser, Marion County (44.93°N, 123.16°W)
First sighting: Azimuth 30°, altitude 30°
Last sighting: Azimuth 0°, altitude 10°
Termination: Disappeared behind trees

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Oregon (continued)

Location: Forest Grove, Washington County (45.63°N, 123.10°W)
First sighting: Azimuth 45°, altitude 60°
Last sighting: Azimuth 15°, altitude 15°

Location: Portland, Multnomah County (45.40°N, 122.67°W)
First sighting: Azimuth 90°, altitude 12°
Last sighting: Azimuth 0°, altitude 10°

Duration: 2-3 seconds for all observers
Magnitude: Brighter than the full moon
Apparent size: 1/2 to equal to the diameter of the full moon
Color: Green
Trail: 15-60° long, green-white color, except Keiser observer saw a yellow-orange and red trail
Sounds: None reported by any observer

Information Contact: Richard N. Pugh, 4617 N.E. 26th Avenue, Portland, Oregon 97211 USA.

Pennsylvania, USA, 14 March, 0845±15 minutes GMT (0345 Eastern Standard Time).
Observer: Paul A. Fillak
Location: Hershey, Lebanon County (40.16°N, 76.39°W)
Path: Straight down in southern sky
Duration: 5 seconds
Apparent velocity: Fast
Magnitude: Brighter than the full moon
Color: Red-yellow
Termination: Fragmented into 2-3 parts before vanishing above horizon
Sounds: None heard

Information Contact: Jeffrey L. Smith, Pennsylvania Historical and Museum Commission, William Penn Memorial Museum Building, Box 1026, Harrisburg, Pennsylvania 17108-1026 USA.

Virginia, USA, 26 March, 0630 GMT (0130 Eastern Standard Time).
Observer: Sherry Talley
Location: Hanover, Hanover County (37.6°N, 77.4°W)
Path: E from behind observer
Duration: 2 seconds
Apparent velocity: Fast
Magnitude: Almost as bright as the full moon
Color: White
Trail: White
Termination: Disappeared behind trees
Sounds: Rushing sound as fireball passed

Information Contact: Paul Knappenberger, Jr., Science Museum of Virginia, 2500 West Broad Street, Richmond, Virginia 23220 USA.

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